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AN EXPERIMENTAL STUDY OF DECENTRALIZED LINK FORMATION WITH COMPETITION

Margherita Comola
Marcel Fafchamps

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ABSTRACT

We design a laboratory experiment to investigate bilateral link formation in a setting where payoffs are pair-specific. Our link formation rule is decentralized and players can make link offers and counter-offers, as in a Beckerian marriage market. The game is designed in such a way that a stable equilibrium configuration exists and does not depend on conditions such as initial configuration or order of move. We test whether the theoretical equilibrium is obtained under experimental conditions, and which individual motivations and decision-making techniques lead players to depart from myopic best response. We find that players are remarkably good at attaining a stable equilibrium configuration, which happens in 86% of the games. Results show that complete information speeds up the game via self-censoring, and that sub-optimal choices are mostly driven by over-thinking behavior and reluctance to accept to link with players who have been disloyal earlier in the game.

Margherita Comola
Paris School of Economics and
Université Paris 1 Panthéon-Sorbonne
Maison des Sciences Économiques
106-112 Boulevard de l'Hôpital
75647 Paris Cedex 13, France
margherita.comola@psemail.eu

Marcel Fafchamps
Freeman Spogli Institute
Stanford University
616 Serra Street
Stanford, CA 94305
and NBER
fafchamp@stanford.edu

1 Introduction

There is a large experimental literature studying the functioning of decentralized markets. Starting with the seminal work of Smith (1962, 1964), an important part of this literature has focused on the price formation process, showing that experimental subjects often converge to a single market clearing price. This finding has been obtained in different settings and cultures (*e.g.*, Holt 1995, Roth 1995, Bulte *et al.* 2014), and participants do not appear to require prompting or guidance to quickly converge to the market clearing price and to achieve a high level of efficiency (*e.g.*, List 2002, 2004).

In this paper we focus on another common form of market interaction in which payoffs of economic agents vary depending on *who* they trade with. For instance, two workers may value two jobs differently, *e.g.*, because of commuting distance. Similarly, two employers may value two workers differently from each other, *e.g.*, because of job-specific skills or attributes. The same holds for many social matching processes – *e.g.*, finding a friend or a spouse. All these processes have the following characteristics in common: (1) link formation is decentralized – there is no Walrasian auctioneer; (2) payoffs are pair-specific – agents value pairing with a given partner differently from each other; (3) there is a upper bound or capacity constraint to the number of links that each agent can form; and (4) offers and counter-offers are allowed – there is competition. This paper explores the extent to which experimental subjects are adept at playing decentralized market games with these characteristics.

To this effect, we design an original laboratory experiment that focuses on decentralized link formation with suitable partners. Following Gale and Shapley (1962), much of the literature on matching games has focused on single matching problems – *e.g.*, marriage market, employer-employee matching, student-class matching (Roth and Sotomayor 1992, Echenique and Yariv 2013). Multiple matching has received less theoretical attention but has been picked up by the network literature (Jackson and Watts 2002, Demuynck and Vandenbossche 2013). Our experiment bridges the network literature that focuses on the determinants of link formation, and the literature on matching games (in our case many-to-many matching, as players are allowed multiple links). For this reason we use the expressions 'link formation' and 'matching' interchangeably in what follows. We extend the well-known single-match problem *à la* Gale and Shapley to a competitive market framework where multiple links are admitted and agents preferences are pair-specific, that is, fully heterogeneous across players and across links. This payoff structure has the advantage of mimicking the interaction of common preferences and homophyly, which are believed to be the two main forces behind matching processes in real-life contexts.[1]

Several equilibrium concepts have been proposed for bilateral network formation games. They all originate from pairwise stability (PS), a concept initially introduced by Jackson and Wolinsky (1996). To satisfy pairwise stability, an equilibrium shall contain only and all the links that are beneficial to both parties involved, which is a natural requirement for link formation with mutual consent. We refine pairwise stability to allow agents to deviate in coalitions of size two, that is, we allow a pair of agents to cut some of their pre-existing links to simultaneously form a new link between them. This allows players to compete through counter-offers to potential partners. This equilibrium concept is close in spirit to what Becker calls a stable marriage market, and has been named 'strong pairwise stability' (SPS) by Belleflamme and Bloch (2004) in the context of network formation. SPS offers several advantages relative to PS. First, it combines voluntary exchange (the PS part) with competition through offers and counter-offers (the 'strong' PS part). This is desirable because it better represents decentralized market processes. Second, relative to PS, SPS significant reduces the number of equilibria, a problem that has plagued previous experiments on bilateral network formation (Deck and Johnson 2004, Di Cagno and Sciubba 2008, Burger and Buskens 2009).

Our original experimental protocol extends the Gale-Shapley algorithm to multiple links, leaving participants free to compete for potential partners. Formally, subjects are asked to form links with (up to two) other experimental subjects in a sequential and decentralized way. Link formation requires mutual consent and only direct links affect

[1] It can be rationalized with a simple model displaying heterogeneity along two dimensions: each player is endowed with an individual parameter q_i representing his quality as a partner (common preferences), each pair of player is assigned a relational parameter d_{ij} representing their socioeconomic distance (homophyly), and the payoff of i from forming the link ij is $q_j - d_{ij}$.

individual payoff (*i.e.*, there are no externalities from indirect connections).[2] Because of tractability issues, a payoff function of this kind has been rarely investigated in the context of bilateral link formation and, to the best of our knowledge, it has never been approached experimentally. Our game is designed in such a way that a SPS configuration exists and interaction among subjects is guaranteed to lead to an SPS configuration if participants play a myopic best response strategy. The first objective of our experiment is to investigate to which extent experimental subjects converge to the SPS equilibrium in the laboratory. The experimental literature has documented that participants in games of strategic behavior seem to face difficulties in identifying which strategy to select, especially when they lack a heuristic from their everyday experiences to guide their choice.[3] We wish to ascertain the extent to which similar difficulties arise in decentralized matching games with competition.

The second objective is to shed light on which individual motivations and decision-making techniques make subjects unable to reach the SPS equilibrium. In order to do so we introduce four main treatments to test different hypotheses regarding strategic behavior in decentralized matching games. In the first treatment we allocate subjects to randomly assigned links at the beginning of the game. In contrast, subjects in the control experiments begin the game with no link. In our game the initial network configuration should not matter as long as subjects play myopic best response. However, if subjects display inertia or loyalty to existing links, we expect a lower rate of convergence to the SPS equilibrium when subjects start with randomly assigned links. In the second treatment we provide full information about all payoffs of all other players. This stands in contrast to the control experiments where subjects only observe their own payoffs. In our game, information about own payoffs should suffice to reach the SPS equilibrium as long as subjects play myopic best response. The role of full information is thus *a priori* unclear in this context. On one hand, full information may

[2]To avoid making the experiment too complex, we also 'switch off' the possibility for subjects to negotiate over contract terms such as link price. This is equivalent to assuming non-transferable utility.

[3]Significant deviations from rational play have been found in many experimental games (Gintis *et al.* 2006, Kahneman 2011). These deviations seem more prevalent in games that are cognitively challenging (Camerer *et al.* 2004, Costa-Gomez and Crawford 2006). But they arise even in games that are seemingly straightforward, at least to economists (*e.g.*, Crawford and Iriberri 2007, Caria and Fafchamps 2015).

speed up convergence if better informed subjects refrain from making offers that are doomed to be rejected. On the other hand, it is difficult for subjects to compute the SPS equilibrium even when information about payoffs is fully disclosed. Consequently, full information may confuse players and prevent them from reaching an equilibrium configuration. In the third treatment we vary the distribution of links in the SPS configuration by introducing so-called 'unbalanced' games where certain players are unable to form two links in equilibrium. If link formation is affected by other-regarding preferences (*e.g.*, Fehr and Schmidt 1999, Blanchflower and Oswaldt 2004), players may seek to 'co-opt' these unfortunate players, thereby reducing convergence to the SPS equilibrium. In a fourth treatment, we investigate whether difficulties in reaching an SPS equilibrium arise when the game admits multiple SPS configurations – possibly as a result of coordination failure.

We find that players in the lab attain the SPS equilibrium in 86% of the games. When the SPS equilibrium is not reached, most SPS links are nonetheless formed. SPS thus predicts the overwhelming majority of formed links in spite of the complexity and the sequential nature of the game. One candidate explanation is that competing for mates (*e.g.*, sexual partners, team mates) is an evolved human behavior that long predates the emergence of markets. As a result, the human mind may be naturally attuned to it, in a way that is captured by the SPS equilibrium. If this confirmed by further research, it means that strong pairwise stability may be a useful predictor of behavior in decentralized link formation games of the kind we study here.

We also provide evidence on the reasons for departure from myopic best response. We find no evidence of link inertia and no evidence of coordination problems in the presence of multiple SPS equilibria. Information on others' payoffs speeds up convergence but is not essential for reaching an SPS configuration. Whenever the SPS equilibrium is not reached, it is mostly because subjects reject dominating offers. These sub-optimal decisions appear to be driven by two factors. The first one is players' tendency to over-think: they attempt to act strategically in a setting that does not require either strategy or coordination to converge to the competitive equilibrium. The second factor is that players seem to (incorrectly) condition their offers and acceptances on past play: they seem reluctant to link to players who have rejected them before, even when doing so is in their interest.

This paper contributes to the existing literature in several ways. First, we provide a link between the literature on network formation and the literature on matching games by extending the well-known single-match algorithm *à la* Gale and Shapley to a competitive market framework where multiple links are admitted. Secondly, we contribute to the growing experimental literature on network formation. Gathering evidence on network formation from field data is problematic because of the many confounding factors such as unobserved heterogeneity and homophyly. Lab experiments provide a valid alternative – see Kosfeld (2004) for a survey. Perhaps because of the issue of equilibrium selection, few experimental papers have dealt with bilateral link formation.[4] Out of the existing studies, only two deal with pairwise stability. Kirchsteiger *et al.* (2013) incorporate an element of farsightedness into the notion of PS and provide experimental evidence rejecting myopic behavior. Carrillo e Gaduh (2012) study individual behavior and convergence to the stable network configuration in games admitting unique, multiple, or no PS equilibria respectively. Our experiment is closest to these two studies but it differs from them in two important dimensions. First, we allow two-players deviations: strong pairwise stability keeps our theoretical framework tractable by ruling out the equilibrium multiplicity inherent to pairwise stability. It also alleviates the need for farsightedness in order to coordinate (Kirchsteiger *et al.* 2013). This allows us to offer the first experiment on link formation that integrates heterogeneity and competition – two key features of real-life decentralized markets. Secondly, we use information on individual play to test deviations from myopic best-response, with a view of identifying what patterns of individual behavior lead to a failure of convergence to an equilibrium configuration.

The paper is organized as follows: Section 2 introduces the matching process and

[4]Di Cagno and Sciubba (2008) and Conte, Di Cagno and Sciubba (2009) study player's coordination in a linking game with indirect externalities where all players simultaneously submit link proposals without communication, and they find little evidence of convergence to a stable network. Burger and Buskens (2009) investigate whether theoretically stable networks are stable experimentally, depending on whether the externalities from indirect contacts are null, positive or negative, and conclude that emerging networks tend to correspond with the predicted networks. In a spatial cost topology, Deck and Johnson (2004) study how the experimental network architecture performs in term of efficiency with respect to the largest possible social payoff, depending on who pays for the linking costs.

the experimental design, Section 3 provides information about the four main treatments, and Section 4 discusses the results. More treatments are discussed in Section 5, and Section 6 concludes. Figures and tables are reported at the end of the paper. Screen shots from the computer interface are illustrated in Appendix A. The written instructions for players are reproduced in Appendix B.

2 Experimental design

Our experiment was funded by the Paris School of Economics. Experimental sessions took place in the Parisian Experimental Economics Laboratory (LEEP) between January 2013 and June 2015. The software used was coded specifically for this experiment by programmers at the LEEP (in HTML, Javascript and Regate[5]).

All participants were students enrolled in the University Paris 1 Pantheon-Sorbonne at the time, without distinction of field or discipline. In total we have 48 groups of exactly 6 players each, which are distributed over 17 experimental sessions.[6] The average payment at the end of the experiment is 20.8 euros for about 1.30 to 2 hours of presence in the laboratory. Half of these players (24 groups) played our main experimental protocol which includes four treatments, on which we focus our attention in what follows (Sections 2 to 4). The other half of players (24 groups) played two modifications of the main protocol that we discuss in Section 5.

In what follows we start by describing the matching process which is the core of our experimental design. We then specify the practical conditions under which the experiment was held and we introduce the details of the protocol.

[5]Regate is an experimental program and language created by Romain Zeiliger (https://www-perso.gate.cnrs.fr/zeiliger/regate/regate.htm).

[6]We had 14 sessions with 3 groups, and 3 sessions with 2 groups. We need groups of exactly 6 players, therefore we always invited more students that strictly necessary (the show-up fee for overbooked students was 7 euros).

2.1 The matching process

In order to design a many-to-many matching game, we sought inspiration from different matching algorithms that allow for competition through offers and counter-offers. These algorithms differ in whether they loop through network configurations, players, or pairs. They also differ in terms of speed and computational efficiency. In spite of these differences, all these algorithms converge to the same stable match, *i.e.*, the SPS equilibrium. After some experimentation, we selected an experimental design inspired by the marriage market algorithm of Gale and Shapley (1962), but extended to a setting with multiple links.[7]

Participants play a sequence of games together. Each game is organized, as in a board game, as a sequence of rounds divided in turns. Within a round, each of the players gets his turn to play. The order of players within a round changes randomly across rounds. When his turn comes, the selected player is allowed to sever existing links and to make linking offers to other players. Each of these offers is either rejected or accepted – more about this below. At each moment, a player can only hold a maximum of two links. As in a Gale-Shapley algorithm, this process of offers and acceptances continues until an entire round takes place without any change in links. The set of links when the game ends determines the players' payoff for that game.

The first reason for choosing this protocol is that it is intuitive to participants. Making and receiving offers is something people seem to be familiar with in their everyday life – *e.g.*, making an offer on a flat, procuring a service from a contractor, inviting someone for dinner. Selecting for the lab a matching process that allows a natural form of interaction increases the likelihood that our experiment brings to light behavior

[7]In the Gale and Shapley's algorithm, all men start by simultaneously making an offer to their most preferred woman. Women then conditionally accept the best offer they received and reject all the others. In the next round, each man without a conditionally accepted offer makes an offer to a woman who did not refuse his offer in the past. This woman then either reject the offer, or accept it, in which case any conditionally accepted offer she was holding is voided. The sequence of offers and conditional acceptances continue until no more offers are made. The resulting set of matches is a stable marriage equilibrium, that is, an SPS equilibrium of a network formation game where only one link with a person of the other sex is allowed. Perhaps the best known application of this algorithm is the National Resident Matching Program, which matches physicians and residency programs in the United States.

patterns that are predictive outside the lab. Second, computer simulations and piloting with human subjects both indicate that, for our experimental design at least, cycling over players is faster than alternative algorithms, such as cycling over pairs ('dyads') or cycling across network configurations. Much care was devoted to create a computer interface that is both informative and intuitive for players.

2.2 Experimental setting

At the beginning of a session, players are randomly divided into groups of 6 players, and assigned a letter identifier from A to F. Each group plays four games with each other. The composition of the group remains unchanged across the games but letter identifiers are reshuffled at the end of each game. This is done to avoid individual reputation effects.[8] Each game follows the sequence of rounds and turns described above. The game ends when the network configuration remains unchanged for one entire round (*i.e.*, 6 turns with no change), or at the end of the 8^{th} round, whichever is less.[9]

There are two types of situations in which players act: when it is their turn to move, and when they are responding to an offer. For simplicity, we call the first role 'mover' and the second 'respondent'. Within his own turn, a player ('mover') can take actions of two types: (1) he can sever a link he holds; and (2) he can offer to link with another player he's not linked to. Each of these actions is called a move. A mover can never hold more than two links at any given moment: if he already holds two links and makes a new link proposal, he must specify which existing link he is willing to drop if the offer is accepted.[10]

[8]Each player sees on the screen a circle with himself at the bottom ("ME" - followed by his current letter) and the other 5 players around, labelled with their respective letters. While ME stays always at the bottom, the other players' letters are visualized in clockwise order (*i.e.* C will be always between B and D). We reshuffle the individual identity at the end of each game, for instance a certain player can see himself as "ME (D)" in a game, and then in the following game he sees himself as "ME (A)", and all other identities have been reshuffled accordingly.

[9]This feature is included to prevent endless cycling. In practice, only 5% of all games reach the 8^{th} round without having converged.

[10]For instance, if mover A already holds two links, say with B and C, and offers to link with D, A must first specify which link, B or C, he would like to sever in case D accepts the offer. This decision

Within his turn the mover can do multiple moves of the types explained above, in a sequential order of his choice: he can sever one or more links, and he can make offers to some or all the other players. To avoid cycling within the turn, we only impose that a mover can: (1) unconditionally sever only the links he holds when the turn began; and (2) only propose new links that did not exist at the beginning of the turn.[11] Movers have 15 seconds per move. If they fail to take any action, by the end of the 15 seconds they are considered having forfeited their turn and the game moves onto the next player. However, they can make multiple moves during their turn, and for each move the 15-second limit applies.

During another player's turn, any player ('respondent') may be called on to accept or reject a linking offer. If the respondent holds less than two links, he can either accept or reject the offer directly. If the respondent already holds two links, at the moment of accepting he has to specify which of these two links will be severed.[12] If the respondent decides not to drop one of his two links, the offer is considered rejected. Respondents have 15 seconds to accept or reject an offer. If they do not take any action within that time interval, they are considered as having rejected the offer, and the game continues.

All linking offers made and received remain private information between the two players involved until an offer is accepted and a new link is formed.[13]

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must be made before knowing whether D accepts the offer.

[11]This means that, within a turn, a mover can only make a maximum of 5 offers (fewer if he is already holding links). But nothing prevents a mover to re-propose the same link when it is his next turn to play. Also, a link can be formed and severed within the same turn, but only as a consequence of getting another offer accepted. Here is an example of a particularly long but feasible sequence of moves: starting with no links, player A offers to link with B; the offer is rejected; A offers to link with C; the offer is accepted (A now holds one link); A offers to link with D; the offer is accepted (A now holds two links); A offers to link with E and commits to drop the link with C if accepted; the offer is accepted (the link with C is dropped and the link with E is added); A offers to link with F and to drop the link with E if accepted; the offer is rejected. Since A has made offers to all other players within this turn, he cannot make any more offers and the turn ends.

[12]For example, suppose that mover A proposes to D who already holds two links, say with E and F. Repondent D wishes to accept A's offer. To do so, D must first specify which link, E or F, he severs when accepting A's offer. This guarantees that D never holds more than two links.

[13]To illustrate, imagine that player A has two links (to B and C) and player D also has two links (to E and F): if during his movement A makes an offer to D by conditionally dropping his link to B but the offer gets refused, neither B (directly involved) nor C, E and F will ever be informed of the offer made. On the other hand, if the offer is accepted everyone will see the new network configuration immediately appear on the screen.

A detailed description of the computer interface is given in Appendix A.

2.3 Payoffs

A key feature of our experiment is that payoffs are pair-specific, that is, fully heterogeneous across players and links. To illustrate, let i's payoff from forming a link with j be denoted π_{ij}.[14] We do not require that $\pi_{ij} = \pi_{ji}$, that is, we do not impose that two players need to benefit equally from the link. In other words, j may be the most desirable partner for i even though i is the least desirable partner for j. We also do not require that $\pi_{ij} = \pi_{kj}$, that is, we do not impose that two different players value linking with j equally: j may be the most desirable partner for i but the least desirable partner for k.[15] The lack of correlation between π_{ij} and π_{kj} means that i's gains are not informative about others' gains: if information about other players' payoff is not provided in the experiment, players cannot infer anything from their own payoffs. We do, however, require that $\pi_{ki} \neq \pi_{kj}$ for all k, i and j. This requirement implies that each player has a strict ranking over all other players; this guarantees that there are no ties. Operationally, this is achieved by setting a payoff vector of the form $[10, 30, 20, 50, 40]$ where the order of the five payoff values has been independently randomized for each player.[16]

Because randomization is done independently by player, it can happen that one player is generally more desirable for all or most other players. For instance, it is possible that, in some game, the payoff matrix is such that $\pi_{AB} = \pi_{CB} = \pi_{DB} = \pi_{EB} = \pi_{FB} = 50$. In this case, player B is the most desirable partner for all subjects. Since players can only hold two links, this means that not everyone will be able to link to B. In this particular case, we would expect B to receive offers from everyone, and to accept those that are the highest, those worth 50 and 40 to him. Alternatively, a player, say C, may only be desirable for players from whom C would gain little. In this case, C

[14] There are no gains from self-links, *i.e.*, $\pi_{ii} = 0$.

[15] In the parlance of the marriage market literature, the latter condition is equivalent to assuming no common preferences.

[16] Note that, since all links yield a positive payoff, any outcome in which players hold two links is a PS equilibrium. This is because no player wishes to unilaterally deviate by dropping a link since doing so always reduce the player's payoff.

may only secure a low payoff. The point of these examples is to draw the attention to the fact that payoffs need not be equalized across players even though they all face the same five values in their payoff vector.

The total payoff of each player at the end of a game is simply the sum of the gains from the links he holds when the game stops.[17] At the end of the experiment, we randomly draw one of the four games played by the group in the session, and players receive their total payoff from that game.[18] This ensures that participants have a material incentive to form the most profitable links in each of the four games they play.

2.4 Equilibrium and convergence

In order to generate the payoff matrices used in the lab game, we proceed as follows: we first generate random payoff matrices with the features described in Section 2.3, and then we check for the existence and the characteristics of the SPS equilibrium. This is done computationally: to make sure that each selected payoff matrix has (at least) one SPS equilibrium we loop through *all* possible network configurations, verifying for each configuration whether it is SPS for that specific matrix.[19] The retained payoff matrices are those used in the experiment.

Our experimental protocol displays three key features related to the SPS equilibrium. First, the SPS equilibrium configuration is fully determined by the payoff structure of the game. This means that we can vary a number of experimental conditions (for example the initial network configuration) and we still have the same SPS equilibrium of reference. This allows us to test several hypothesis about the individual motivations behind linking choices.

Secondly, our experimental protocol is robust to individual mistakes. Recall that the game ends only when there is no change in the network for an entire round. This means that, by the time the game ends, each player has had the opportunity to either sever existing links (and choose not to) or to make new offers (and if he did, they were not

[17] For instance, if i is linked to j and k, then i's payoff for that game is $\pi_{ij} + \pi_{ik}$.

[18] The conversion rate was 0.2 euros per point of gain, plus a fixed payment for participation.

[19] This is computationally burdensome, but feasible in our case because the number of players in a group is small.

accepted).[20] Also, since payoffs do not fall across rounds, there is no penalty if the game continues, the only thing that matters is the final outcome. Thus, individual mistakes can be easily corrected, links previously severed can be re-formed at no material cost, and offers previously declined can be re-made and accepted as long as the players involved change their mind.

Thirdly, players do not need much information in order to play this game successfully. As long as a player knows his own payoffs and is willing to make offers, he can select the best partners out of those who are willing to link with him (possibly because they have no better offer on their plate). Full information on the payoff of potential partners may be useful in that it may speed up the game through self-censoring. But it is not necessary for convergence if players are patient enough and are willing to continue making offers. On the other hand, even if the entire payoff matrix is disclosed, from a player's perspective it is virtually impossible to compute the SPS equilibrium: there are so many feasible network configurations that even the most mathematically gifted subject could not work out the SPS without a computer. Thus, our experimental protocol is complex but convergence does not require complex thinking. This gives us the opportunity to explore whether experimental subjects respond positively or negatively (*e.g.*, information overload) to the amount of information they receive.

Although proving this formally is beyond the scope of this paper, we believe that for the well-chosen payoff matrices described above, the sequence of offers and acceptances converges to a SPS equilibrium whenever three requirements are met. The first requirement is that movers should not make dominated offers (*i.e.* an offer which, if accepted, would lead the mover to drop a link that yields a higher payoff than the one he's proposing) - or if they do, they correct themselves later on in the game. The second requirement is that respondents do not reject dominating offers (*i.e.* an offer that yields a payoff higher than any of the links currently held by the respondent) - or if they do, they correct themselves later on in the game. Whenever players comply with the two requirements above, we say that they are playing a 'myopic best response strategy', choosing actions that maximize one's payoff based on the current state of

[20] Note that a player cannot prevent convergence by indefinitely making offers: if a complete round takes place without any of these offers being accepted, the game stops.

play, and ignoring any future play. The third requirement is that enough players make enough offers for a long enough time – convergence would fail if all players consistently refrain from making offers that are part of the SPS equilibrium.

There are many possible reasons why players may deviate from the three behavior patterns listed above. For example, players may make dominated offers in order to increase the payoff of another player whom, in their eyes, needs to be rewarded or is receiving an unfairly low payoff. They may reject dominating offers because they believe the other player is benefitting unfairly from the link, or because they want to punish that player for rejecting them in the past. They may stop making offers early if they have satisficing preferences and do not wish to search more. Documenting these departures from myopic best response is a central objective of our paper.

3 The treatments

Our experimental protocol naturally has multiple sources of experimental variation, such as the variation in payoff vectors across players and the variation in the order of turns within a round. These sources of variation will be used to study the factors affecting convergence to an equilibrium. We also introduce four main treatments that we describe in what follows. Two additional modifications of the main protocol are discussed in Section 5.

3.1 Initial network

In the control games, the initial network configuration is empty – *i.e.*, players start the game with no links. Our first treatment introduces games in which all players start with 2 randomly-assigned links. We call this $T1$ in the regression analysis of Section 4.

When players start with no links, their initial payoff is 0. They thus have an incentive to make offers in order to achieve a positive payoff. In contrast, when a player starts with two links, the player can obtain a positive payoff even without doing anything. This may induce them to do nothing, for a variety of causes. One possibility is the presence of an endowment effect that creates a reluctance to drop randomly assigned links (*e.g.*, Kahneman Knetsch and Thaler 1991, Rabin and Thaler 2001, Koszegi and Rabin 2009). Another possibility is that players follow a satisficing heuristic (*e.g.*, Simon 1956, Nelson and Winter 1982), *i.e.*, they stop trying to improve on a satisfactory outcome by making or accepting new offers. It is also conceivable that players feel some (misplaced) loyalty towards players to whom they have been linked at the beginning of the game – a bit like pupils who have been randomly assigned a seat in the class and feel some sense of loyalty towards the pupil in the seat next to them. If any of the motivations above prove valid, we expect a lower rate of convergence to an SPS equilibrium under $T1$.

3.2 Payoff information

In the control games, players only observe their own payoffs (*i.e.* i only observes π_{ij} for all j). In other words, they can only tell which links are most beneficial to themselves. We introduce a full-information treatment (called $T2$) in which players observe the entire payoff matrix. In this treatment, player i observes not only his own payoffs, but also the payoffs that other players would obtain from different links and hence who they would most prefer to link with. Operationally, this is achieved by introducing an additional functionality to the screen: in a full information game, i can observe the entire payoff vector of any other player j by hovering the mouse over j's icon.[21] Figure A2 shows a snapshot of the screen that players could see during a game with full payoff information by moving their mouse. We see the screen of player F at a particular moment of the game when it is F's turn to play – he has no links and he is currently browsing the payoffs vector of player A before deciding whether to make him an offer. Figure A2 is a good illustration of the considerable development effort that went into designing a player interface that contains all the relevant information, but remains as intuitive and visual as possible, so as to keep the cognitive burden of the game as low as possible. In control games where players can only observe their own payoffs this feature is switched off (Figures A7-A9).

By accessing this information, a player may gain an idea of the likelihood that an

[21] A proper understanding of this functionality is carefully tested during the training session. We also record how much time players spend browsing the gains of others, which is used in the analysis of Tables 3 and 5.

offer would be accepted. As a result, players may refrain from making offers they think will be rejected – perhaps to speed up the game, or because each rejection entails a psychological cost (*e.g.*, Hitsch Hortacsu and Ariely 2010, Belot and Francesconi 2015). Self-censoring of this kind may speed up convergence – less time is spent making doomed offers. It may also hinder convergence if players refrain from making offers they think will be rejected, but in fact belong in the SPS equilibrium. The reader may think that, once the payoff matrix is known, it is easy enough to compute the SPS equilibrium. This is actually not the case – even less so when players are only given 15 seconds for each move. Thus, knowledge of others payoff may be detrimental if player try to act strategically in a setting where strategic behavior is not necessary, and where the SPS equilibrium is not computable. The possibility of self-censoring does not arise in the control treatment. Even in the full information treatment, players may decide not to check other players' payoffs – playing myopic best response, for instance, does not require it, and still leads to the SPS equilibrium.

3.3 Unbalanced or multiple SPS equilibria

Some of the experimental variation across games stems from differences in payoff matrices. As explained earlier, in the main protocol player payoffs take five values [10,20,30,40,50]. The retained payoff matrices differ along two dimensions that identify two treatments: whether the resulting equilibrium is 'balanced' or 'unbalanced' (which is explained in what follows); and whether there is one or two SPS equilibria.

In control games we only use payoff matrices with a single SPS configuration that is 'balanced', in the sense that all players have 2 links each in the SPS equilibrium, making 12 links overall.[22] In the third treatment (called $T3$) we introduce matrices for which the SPS configuration is 'unbalanced', in the sense that it has 10 links in equilibrium.[23] In unbalanced games, payoffs and number of links are more unequally distributed. Hence, if link formation is affected by other-regarding preferences (*e.g.*,

[22]There are only two network configurations allowed in this case: either all players form a circle; or there are two circles with three players each.

[23]Either two players are linked to each other and the others form a circle of four players, or one player has no link and the other five players form a circle.

Fehr and Schmidt 1999, Blanchflower and Oswaldt 2004), *ceteris paribus* we expect a lower likelihood of convergence to the SPS configuration in an unbalanced game.

In control games, there is a single SPS equilibrium. We introduce a fourth treatment (called $T4$) where the payoff matrix admits two SPS equilibria.[24] When a game has a single SPS equilibrium, the order of turns (which is randomly assigned) should not matter for convergence. When a game admits two SPS configurations, the order of turns may play a role in selecting one equilibrium out of the two. This is what would happen, for instance, if players always stick to myopic best response: in this case, the SPS equilibrium would be selected by the order of play. With two SPS configurations, it may be more difficult to converge to an SPS equilibrium – for instance because of coordination failure, as players attempt to steer the game towards different SPS configurations. We therefore conjecture that convergence to an SPS equilibrium may be less frequent and may take more time when there are two equilibria.

3.4 Sequencing of treatments

We present in Table 1 the sequence of treatments across the 24 groups of 6 participants that form the core of our experiment (96 unique games in total). Each letter denotes a particular combination of $T1$ (initial network) and $T2$ (payoff information): A stands for empty initial network and own payoff information only; B stands for empty initial network and full payoff information; C stands for full initial network and own payoff information only; and D stands for full initial network and full payoff information. Table 1 shows how the the first two treatments are crossed in a systematic and symmetric way: with 24 groups we are able to implement each of the 24 possible order permutations of the four treatment combinations *A, B, C* and D.[25] This enables us to disentangle treatment effects from a game order effect, *e.g.*, due to learning. Also, letters that are underlined indicate games in which the SPS equilibrium is unbalanced, *i.e.*, has only 10 links. It is clear from Table 1 that balanced and unbalanced SPS equilibria are distributed evenly across groups and letters. Finally, letters in green indicate the 12

[24]Note that only balanced games may admit two SPS configurations.

[25]Note that the first block (group 1 to 12) plays almost the same sequence as the second block (group 13 to 24), except that the third and fourth letter are switched.

balanced games that admit two SPS equilibria, whose allocation was let random.

It is important to realize that games with the same letter in Table 1 share common features but they are not identical. To illustrate, consider two $\underline{C}$, that is, two unbalanced games with a full initial network and own payoff information only. These games share common features – each player starts the game with two randomly assigned links, and there are 10 links in the SPS equilibrium. But they differ in many other respects: a different payoff matrix (and thus a different unbalanced SPS configuration); a different initial network configuration; and a different order of turns. This implies that when groups 1 and 2 play game $\underline{C}$, they play two different link formation games. We have done so in order to disentangle the effect of the treatments from specific structural properties of the network configurations that we generate.

4 Main results

We start the empirical analysis by examining whether players converge to an SPS equilibrium across the different games played in the lab. We then turn to the analysis of the different treatments on outcomes, where we analyze our data at three different levels: game, link, and action. Throughout this section we focus on the main blocks of experiments (the 96 games described in Sections 2 and 3 and presented in Table 1). Results from additional sessions testing ancillary hypotheses are discussed in Section 5.

4.1 Outcomes

We start by noting that the SPS equilibrium is a strong predictor of experimental outcomes. In 83 of 96 games (86%) players converge to an SPS equilibrium. And in the 13 games where the SPS configuration is not reached, 70% of the SPS links are nonetheless created and the aggregate payoff is close to the aggregate payoff of the SPS equilibrium (399 *versus* 413 experimental points on average).[26]

[26] Out of the 13 games where an SPS equilibrium is not reached: 4 are under-connected (*i.e.* they have 5 links *vs.* 6 in the SPS equilibrium); 5 are over-connected (*i.e.,* they have 6 links *vs.* 5 in the SPS equilibrium); and 4 have the correct number of links, but some of them do not belong to the SPS equilibrium.

Could these results have been generated by chance? To investigate this possibility, we generate, for each game, random networks with two links per player. As noted earlier, each of these is a PS equilibrium by construction. By generating 100 such networks for each game, we approximate the distribution of links under the null hypothesis of random networks. We find that, on average, random PS networks have 37% of the SPS links – compared to over 96% across all our experimental networks. Since 99.3% of the randomly generated PS networks have 80% or fewer SPS links, we firmly reject the random networks null hypothesis. In other words, the likelihood that these results were obtained by chance is vanishingly small. Incidentally, this also implies that pairwise stability is a poor predictor of outcomes in our experiment.

4.2 Games

Next we turn to variation in game outcomes due to the treatments. We start by reporting an analysis of results from the 96 games presented in Table 1. Table 2 reports the results of linear regressions of the form:

$$y_i = \beta_0 + \beta T_g + \lambda_g + \lambda_{gr} + \lambda_s + \varepsilon_i \qquad (1)$$

where y_i represents an outcome variable for game i to be described in what follows. The vector T_g represents the four game-level treatment dummies discussed in Sections 3.1 to 3.3: dummy T_1 equals one if the initial network configuration is non-empty (*i.e.,* the game starts with two randomly assigned links per player). The dummy T_2 equals one if the game was played under full information about the payoff matrix. The dummy T_3 equals one if the SPS equilibrium is unbalanced (*i.e.,* has 10 links instead of 12). The dummy T_4 equals one if the payoff matrix admits two SPS equilibria. We include the game fixed effects λ_g (*i.e.* a set of dummies for the order in which the game was played from 1 to 4), the group fixed effects λ_{gr}, and the session fixed effects λ_s to allow for possible common shocks. Standard errors are clustered at the group level, which is the highest level at which participants interact in the experiment.

We estimate model (1) for several outcome variables. In the first column of Table 2, the dummy dependent variable y_i equals one if the game converged to an SPS equilibrium. In column (2) the dependent variable is the share of SPS links formed in the final network configuration – *i.e.*, out of the links that exist when the game stops. In column (3), the dependent variable is the total number of links formed. In column (4) the dependent variable is the sum of all the payoffs obtained at the end of the game, which is an indicator of efficiency.[27] In column (5) it is the total number of rounds played; in column (6) is the number of accepted proposals; and in column (7) it is the number of rejected proposals.

The regression results presented in Table 2 indicate that none of the four treatments under analysis affects whether players reach an SPS equilibrium or the share of SPS links they form. In other words, the finding that players consistently converge to the SPS equilibrium is robust to all four treatments.

The full complete information treatment T_2 significantly increases the total number of links as well as efficiency. It also decreases the time needed to converge and the number of rejected offers. The increase in efficiency arise due to three combined effects. First, as shown in column (3) of Table 2, players form more links under full information, and this tends to mechanically increase the sum of payoffs. Secondly, when players do not reach the SPS configuration, they still achieve a higher aggregate payoff under full information: in the incomplete information treatment, the aggregate payoff is lower than in the SPS equilibrium for 5 out of the 6 games where the SPS equilibrium is not reached; in the full information treatment, this is observed in only 2 cases out of the 7 games where the SPS equilibrium is not reached. Thirdly, when the game has two Pareto ranked SPS equilibria, under full information the high equilibrium is selected much more often: there are 9 games with a low and a high equilibrium in Table 1; in all the 4 such games with incomplete information, play converges to the low SPS equilibrium while in all 5 games with full information it converges to the high SPS equilibrium.

The reduction in the number of rounds before convergence is largely a consequence of the reduction in the number of rejected offers. On the other hand, there is no treatment effect on the number of accepted offers. What this seems to suggest is that,

[27]It is important to keep in mind, however, that the SPS equilibrium is not always the efficient match.

in the full information treatment, players are less likely to make offers that they can predict will be rejected. This constitutes evidence of self-censoring of the kind discussed in Hitsch, Hortacsu, and Ariely (2010) and Belot and Francesconi (2015), but in the context of a laboratory experiment. In Section 2 we argued that players may not be able to precisely predict which offers would be rejected, and that this may result in excessive self-censoring that would ultimately prevent players from reaching an SPS equilibrium. The laboratory evidence suggests that, under our experimental conditions, these fears were unfounded.

The unbalanced SPS treatment is shown to reduce the number of links and the aggregate payoff, but these are a mechanical consequence of the fact that the SPS equilibrium has fewer links. Other treatments have no effect on any of the games' aggregate outcomes. In summary, contrary to expectations, convergence to an SPS equilibrium is equally likely and rapid under the treatments with multiple SPS equilibria, unbalanced SPS equilibrium, or a potentially distracting non-empty initial network. This further confirms the robustness of convergence to an SPS configuration.

4.3 Links

We now turn our attention to the effect of experimental conditions on link formation. The unit of observation is the dyad, that is, a pair of subjects that played in the same group. There are $\frac{(6x5)96}{2} = 1440$ such dyads across the 96 games presented in Table 1. We estimate linear regressions of the form:

$$y_{ijg} = \beta_0 + \beta_1 A_{ijg} + \beta_2 X_{ijg} + \beta_3 SPS_{ijg} + \beta T_g + \lambda_g + \lambda_{ij} + \varepsilon_{ijg} \qquad (2)$$

where the dummy y_{ijg} equals one if dyad ij is linked when game g ends. Variables A_{ijg}, X_{ijg} and SPS_{ijg} denote three experimentally assigned, dyad- and game-specific dummy variables: A_{ijg} takes value 1 if link ij appears in the initial network configuration of treatment T_1; and X_{ijg} takes value one when the absolute difference between π_{ij} and π_{ji} is large, *e.g.*, exceeds 20 points.[28] SPS_{ijg} takes value one if link ij belongs to the

[28] $|\pi_{ij} - \pi_{ji}|$ can only take values $0, 10, 20, 30$, and 40. Hence $X_{ijg} = 1$ when the difference is 30 or 40.

SPS configuration.[29]

If players are reluctant to sever pre-assigned links, *e.g.*, because of an endowment or inertia effect, we expect $\beta_1 > 0$: the link is more likely to remain until the end of the game, irrespective of whether it belongs to the SPS equilibrium or not. If subjects are inequality adverse, they may refrain from forming links that yield a very unequal distribution of gains. In this case, we expect $\beta_2 < 0$: the more unequal the distribution of gains is, the lower is the likelihood that the link was formed. Treatment dummies T_g includes the four game-level basic treatments as before. We also include game fixed effects λ_g and dyad fixed effects λ_{ij} as controls. The former are identified by variation across dyads in the same game; the latter are identified by systematic variation across games for the same dyad.

Dyadic regressions typically suffer from correlation in errors across observations. This case is no exception: since players are restricted to two links, the likelihood that i is linked with j is not independent from the likelihood that i is link with k. To correct for this, we cluster errors are the group level. This takes care of any arbitrary patterns of intra-group correlation in errors.

Regression results are reported in Table 3. We find that β_1 is not statistically different from 0: being matched at the beginning of the game has no effect on the final network configuration created in the laboratory. Coefficient β_2 is also not significant – this suggests that inequality aversion does not, in fact, affect link formation in our experiment.[30] As expected, the coefficient of SPS_{ijg} seem to explain most of observed links. The coefficient of T_2 is in line with what reported in the column (3) of Table 2, namely that the overall number of links is larger in the full information treatment. Additionally, the coefficient of T_4 which was already negative in the column (3) of Table 2 becomes now marginally significant.

[29] When there game admits two SPS equilibria, we focus on the configuration which was attained or closer to be attained in the game.

[30] The results from an experiment by Belot and Fafchamps (2012) provide one possible interpretation for this finding. In that experiment, the authors let subjects choose between two allocations of payoffs among four players. These choices are framed either as the division of a pie between four individuals, or as the selection of a partner. The authors find that altruism is much less likely to affect choices in the partner selection frame than in the pie allocation frame. This feature may account for the absence of evidence of other-regarding preferences in our results.

4.4 Actions

We now turn to the actions taken by players within each turn. We are interested in assessing the extent to which players' actions are rational. This is non-trivial because we do not know what dynamic strategies participants may be playing, and hence we have no way of telling whether these strategies are rationalizable, *e.g.*, whether the assumptions they make about other people's strategies are reasonable. What we can do, however, is to document the extent to which actions deviate from myopic best response. Since most games in our experiment converge to an SPS configuration, myopic best response is a useful yardstick: if we find that actions follow myopic best response in the majority of cases, we should not be surprised that games converge to an SPS equilibrium.

In the context of our game, myopic best response dictates that a player should only take actions that can increase its total gains. In particular this implies that offers that are made and accepted should always dominate those that the player currently holds, and players should reject and refrain from making dominated offers.[31] We identify four types of actions that strictly violate myopic best response. For movers these violations are: (1) dropping a link without forming another; (2) proposing a dominated link.[32] For respondents these violations are: (3) refusing a dominating offer; and (4) accepting a dominated offer.

4.4.1 Movers

We first direct our attention to the actions taken by movers – that is, by players whose turn it is to move. To recall, a mover can decide to do nothing, that is, to accept the *status quo* and pass the turn to the next player; or take one or more actions, such as making offers or deleting links without making offers.

[31] Formally, let ij denote the link currently being proposed and let s_i denote the gain that mover i is offering to drop in order to form a new link. If i currently holds less than two links, then $s_i = 0$. If i currently holds two links worth π_{ik} and π_{im} and offers to sever ik if the new link is formed, then $s_i = \pi_{ik}$. The link ij is said to be dominating (for i) if and only if $\pi_{ij} > s_i$; it is said to be dominated if and only if $\pi_{ij} < s_i$.

[32] Failing to making dominating offers may also violate myopic best response, but only weakly: if the player thinks the offer will be rejected, making it would not increase his payoff – and thus is not strictly better. For this reason, we focus on the two actions listed above.

Over the 96 games, we observe 3205 mover actions from 1980 unique turns. 865 (27%) actions consist in keeping the *status quo* and passing the turn. 2340 actions (70%) are active actions. The large majority of active actions (97%) do not violate rules (1) and (2) above. Only 70 active actions (3%) constitute strict violations of myopic best response: in 35 instances the mover drops a link without forming another one; and in another 35 instances the mover offers a link which is payoff-dominated by the link he conditionally deletes.

In Table 4 we report regressions analysis using each turn as unit of analysis. We estimate fixed-effect linear regressions of the form:

$$y_{ir} = \beta_0 + \beta\, X_{ir} + \gamma\, T_g + \delta\, r + \lambda_g + \lambda_s + \lambda_i + \varepsilon_{ir} \tag{3}$$

where y_{ir} is a characteristic (to be described below) of the combined actions taken by mover i in round r. Vector X_{ir} includes three regressors of interest: $time\,history_{ir}$ which represents the number of seconds mover i spends browsing the history of the current game during round r; $time\,gains_{ir}$ which represents the number of seconds mover i spends browsing the payoffs of other players during round r;[33] and the dummy $already\,2\,links_{ir}$ which equals one if mover i already holds 2 links at the beginning of turn r. The rationale for including these regressors is explained below. Other regressors include the four game-level treatment dummies T_g, the round number r (which is meant to capture the effect of time within a game), game fixed effects λ_g, session fixed effects λ_s, and individual fixed effects λ_i.

In the first column of Table 4 we take as unit of observation all unique turns ($n = 1980$). Here the dependent variable y_{ir} is the share of violations of type (1) or (2) in the actions taken by mover i in round r. If information is used by players to refine their action and avoid making mistakes, players who spend more time checking the payoffs of other players and the history of play may take fewer actions that violate myopic best response. Regression results presented in column (1) indicate instead that players who spend more time browsing other players' payoffs are *more* likely to take actions that,

[33] This is zero in the no-information treatment, or if the player did not browse the others' payoffs during his move.

from the point of view of myopic best response at least, appear irrational. Keep in mind that in our game it is virtually impossible for someone to work out the SPS equilibrium through mental calculation – there simply are too many combinations to consider. We therefore conjecture that players who spend much time examining the payoffs of other players end up making sub-optimal decisions because they either over-think the game, *e.g.*, try to solve for the SPS equilibrium; and/or because they try to come up with complex strategies that, in our game, yield no obvious benefit. This interpretation, which will be re-confirmed later on, is comforted by the fact that, over the duration of each session, players seem to learn not to take such actions: the coefficient second, third and forth games are all significantly negative and they increase in magnitude. We find no effect of any of the four treatments on violating myopic best response. This is in line with our earlier observation of Table 2 that most games reach an SPS equilibrium irrespective of treatment. In column (1) we also observe the coefficient of $already\,2\,links_{ir}$ being significantly positive - but this is a consequence of the fact that deviations of type (2) can only occur when the mover already holds two links.

In columns (2) to (4) we focus on what happens when, at the beginning of his turn, a mover is not currently holding the most desirable links (worth 40 and 50). There are 1379 turns for which this is true. In such a configuration, myopic best response would suggest that the player should continue making offers in the hope of securing these two most desirable gains. The links that would generate these desirable gains for the mover need not be in the SPS equilibrium, however. Hence making these offers repeatedly will see them rejected multiple times. Players may attach some subjective dis-utility from repeated rejection, which would lead them to refrain from making such offers. We report this analysis in the second column of Table 4, where the dependent variable y_{ir} takes value 1 if the mover passed the turn without making any action (neither proposal nor severance), and 0 otherwise. We note a strong round effect: the coefficient of r is significantly positive, meaning that players who did not attain the most desirable configuration yet are more likely to make no offers as the game progresses. This is consistent with rejection avoidance – or more generally not wanting to waste time in a satisficing perspective: once players have secured some links, the need to make offers is less pressing. We do indeed find that players who already hold two links are more likely to make no offers. We also observe that making no offer is significantly more frequent in the full information treatment. This confirms our earlier interpretation: movers are more likely to refrain from making offers when they have more information about the payoffs of other players that leads them to expect rejection. In other words, information leads to self-censoring.

We continue this investigation in column (3) where y_{ir} represents the number of 'wish-list' proposals made during the turn – *i.e.*, the number of offers that would increase the mover's gain if they were accepted that were actually made. In column (4) we refine this variable to only include offers to the most desirable potential partner at the beginning of round r.[34] Results confirm earlier findings. Movers are less likely to make wish-list offers when they already hold two links, and in the full information treatment. We nonetheless observe that more wish-list offers are made by players who spend much time examining other players' payoff. The unbalanced SPS treatment marginally increases the number of wish-list proposals in column (3) – possibly because players with no links or one link continue making offers even after the game has settled. We again note, in column (4) fewer top wish-list offers being made in later rounds, which is consistent with decision fatigue – defined as the tendency for inertia to increase as the length of the game increases, regardless of the attained payoff (Danziger Levav and Avnaim-Pesso 2011).

To investigate these issues further, we now take another perspective on the actions taken by movers. We now take as unit of observation all the potential offers that could have been made in each round, and create a dependent variable m_{ijr} equal to 1 if i made an offer to j in round r, and 0 otherwise. We omit all dyads for which an offer could not be made in that round, *i.e.*, because a link ij was already in existence.[35] We further subdivide the observations into two groups: those for which making an offer would increase i's payoff;[36] and those for which making an offer would decrease it. The

[34] This is the player yielding a payoff of 50 if i is not linked with him yet, or the player worth 40 in case the link worth 50 already exists.

[35] This is easily illustrated with an example. In round 1 player A has no link. For this round we have five dyadic observations for player A, corresponding to each of the five offers he could have made, *i.e.*, AB, AC, AD, AE, AF. Now suppose that in round 2 player A has links to C and D. In this round A can make three offers: AB, AE, AF and thus we have three dyadic observations.

[36] If the mover has less than two links at the beginning of round r, all potential offers are payoff-

first group corresponds to dominating offers, which should be made according to myopic best response; and the second group corresponds to dominated offers, which should not be made. We estimate a linear regression model of the following form on each of these two sets of observations separately:

$$y_{ijr} = \beta_0 + \beta\, X_{ijr} + \gamma\, \pi_{ijg} + \delta\, T_g + \zeta\, r + \lambda_g + \lambda_s + \lambda_i + \varepsilon_{ijr} \qquad (4)$$

where y_{ijr} equals one if mover i makes an offer to player j during round r. Vector X_{ijr} includes two regressors of interest that we include to capture the history of play between players i and j during game g.[37] The first regressor in X_{ijr} is a dummy that we call 'previous refusal' and equals 1 if j has rejected an offer from i in an earlier round. This is our most direct test of the self-censoring due to the cost of anticipated future rejection (which may be an emotional cost or simply wasted time). The second regressor that we call 'previous severance' takes value 1 if link ij existed before, and was severed by j earlier. It is important to understand that attempts to re-form a link after previous severances (and/or refusals) do not necessarily signal inconsistency in player behavior, but they may be naturally arising as a result of the sequential process through which the game is organized. As players cycle through offers, it is indeed quite possible that j drops a link with i to form a more advantageous link with k, only to see this better link dropped by k later – at which point he may be willing to return to i.[38] We also control for π_{ijg} directly – the larger the payoff, the more likely that an offer is made. As before, we include dummies for the four treatments, as well as round number, and game, session and player fixed effect. As in earlier regressions, standard errors are clustered at the group level.

Regressions results are presented in Table 5. They indicate that personal history of play during the game does not affect mover decisions to make an offer to another player.

increasing.

[37]Remember that players identities are scrambled between games, so that the history of play between two subjects cannot spill over from one game to the next.

[38]This would be the case for instance if j had the opportunity to move before k's turn: following myopic best response, k shall accept the offer as long as j is better than k's pre-existing links. However, when it is his turn to move, k may propose to other players, and j may be forced to come back to i. This behavior does not signal inconsistency, but is a consequence of the game's unfolding.

This is reassuring because taking offense for past rejection may prevent convergence to an SPS equilibrium. We find no evidence of this kind for movers.

4.4.2 Respondents

Next we turn to players who have received an offer and are called to decide whether to accept it or not – the respondents. We observe 2305 responses. Of these, 2117 (92%) do not violate myopic best response: the respondent accepts dominating offers and rejects dominated offers. In 33 cases (1%) the respondent accepts a dominated offer, and in 155 cases (7%) the respondent rejects a dominating offer. Of these 155 rejections, 94 occur while the respondent has fewer than two links – and thus should take any offer – and 61 when he already holds two links. There is, therefore, a little more evidence of irrationality among respondents, and by far the most frequent form is to refuse a dominating offer.

To explore this behavior further, we take as unit of analysis all 2305 responses and estimate a linear regression model of the form:

$$a_{jir} = \beta_0 + \beta\, X_{jir} + \gamma\pi_{jig} + \delta T_g + \zeta\, r + \lambda_g + \lambda_s + \lambda_j + \varepsilon_{jir} \qquad (5)$$

where a_{jir} equals 1 if player j violated myopic best response by rejecting a dominating offer or accepting a dominated offer from player i in round r. Vector X_{jir} includes the regressors of interest which are described below. The rest of the controls is as before.

Coefficient estimates for equation (5) with no X_{jir} regressor are reported in the first column of Table 6. We observe that, as anticipated, a respondent is less likely to reject an offer that would provide him a high payoff π_{jig}. The full information treatment seems associated with a higher tendency to reject a dominating offer (or accept a dominated offer). To throw some light on this finding, we re-estimate equation (5) with two additional regressors: the time spent by j consulting the history of play during round r, and the time spent examining the payoffs of other players (this can only be done in the full information treatment). We find that when these regressors are included, the full information treatment dummy is no longer significant – and even gets a negative coefficient. This agains suggests that spending much time consulting the payoff vector of other players is associated with deviation from myopic best response. This is in line with our earlier, similar finding for movers: deviation from myopic best response seems to occur when players are trying to figure out the best overall strategy given the complete payoff matrix of the game – something that, in this game, is very difficult to do well (and is not needed to ensure convergence). This means that providing full information on others' payoffs can be a distraction for players, but a distraction that, in our experiment, at the end of the day did not prevent convergence to an SPS configuration.

In columns (3) and (4) of Table 6, we include the same two X_{jir} regressors that we had used for equation (4), namely: previous refusal by i of an offer from j; and previous severance by i of a link with j. In both cases we find a positive effect, significant at the 10% level, on the likelihood of violating myopic best response. As noted above, refusing a dominating offer is the main source of departure from myopic best response in our experiment. What columns (3) and (4) suggest is that this behavior is due in part to a refusal to link with players who have 'mis-behaved' in the past, *i.e.*, who have reject a previous offer or have dropped a pre-existing link. This is not altogether surprising. If our matching game was about finding a spouse or a business partner, it is very likely that people would take offense at being rebuffed or rejected and would subsequently refuse a come-back offer. The fear that others may take offense, if strong enough, may induce players to hold onto a low value link for fear of not being able to get back to it later on, should a more promising partner prove to be unreliable. What is remarkable is that, in our experiment, these fears were not strong enough to bring the decentralized matching process to a halt and prevent convergence to an SPS equilibrium. But we nonetheless find some evidence that players do take offense for rejection and broken links, and this may, in another setting, impinge on convergence to a competitive equilibrium.

5 Other treatments

As mentioned earlier, we have also implemented two modifications of our main experimental protocol to test two ancillary hypothesis, which we describe in what follows.

5.1 No-PS equilibria

In our main experimental protocol the value of holding no link is normalized to 0, which means that any existing link is pairwise stable: it is better for a player to hold a link than not hold it. In order to relax this feature we invited 12 additional groups of players[39] to play link formation games where the payoff matrices admit no pairwise stable equilibrium other than the unique SPS. In this so-called no-PS treatment, a 'standard' payoff matrix as the ones described in Section 2.3 is modified such that all non-SPS links yield a negative payoff for one of the players involved.[40] The transformation ensures that we keep one SPS configuration, but make sure that no network configuration other than this one constitutes a PS equilibrium. The purpose of this is twofold: to test whether the absence of PS equilibria facilitates and speeds up convergence to the SPS equilibrium, and to investigate whether players ever form links that are not pairwise stable – *e.g.*, out of spite, or to equalize payoffs. If we find that convergence to the SPS is less frequent when a plethora of PS equilibria is available (as in the main experiment) than when they are removed, this would be consistent with satisficing behavior. The rest of the experimental protocol remains unchanged. The sequencing of treatments is the one shown in Table 1, Block 1.

We find that all no-PS games converge to their unique SPS equilibrium, and they do so much faster than in the main sessions. Under the no-PS treatment, the average number of rounds is 2.4 rounds, versus 3.4 rounds in the main sessions. The fact that convergence to the SPS is much more common in the no-PS sessions is consistent with the idea that the presence of many PS equilibria encourages satisficing behavior: players

[39] 4 sessions with 3 groups of 6 players each, from the same population pool as above.

[40] For example, if the ij link is not in the SPS equilibrium, then we set either $\pi_{ij} = -10$ or $\pi_{ji} = -10$. Since the payoff from not linking is 0, this means that this link is not pairwise stable. If the payoff matrix admits two SPS equilibria, we randomly select one of the two as the reference SPS configuration and discard the other by setting one payoff to negative.

compete less than they could and, as a result, do not reach the maximum payoff they could guarantee themselves. Eliminating distracting PS equilibria leads players to the SPS quickly and always.

Given that all games converge to the SPS equilibrium, we cannot conduct the link analysis that we did for the main sessions. But we can examine the actions of movers and respondents in the same way that we did above, that is, to look for evidence of departures from myopic best response. We find that much fewer observed actions deviate from what is predicted by myopic best response (*e.g.*, less than 3% for respondents, compared with 8% in the main sessions). Given the very small proportion of deviation from myopic best response, there is too little variation in behavior to repeat the analysis of equations (3), (4), and (5).

5.2 Partial information

Finally, we have invited 12 groups of players[41] to play what we call a partial information treatment. In this treatment, each player i sees not only his payoff π_{ij} from linking with j, but also j's payoff π_{ji} from linking with him – but he does not see the rest of j's payoff vector, that is, we do not reveal to i the payoff that j would get from linking with other players (π_{jk} and π_{kj} for all other j, k). This information treatment lies in between the control games (where the player sees only his own payoff) and the full information games (where the player has access to the entire payoff matrix). The possibility of self-censoring is present here as well, but because the game is less cognitively challenging than the full information treatment, the self-censoring effect may even be stronger. Here too we used the treatment sequencing of the Block 1 in Table 1, except that partial information replaces full information – *i.e.*, with letters B and D referring now to partial information treatments. The rest of the experimental protocol is the same.[42]

We find that the proportion of games converging to a SPS configuration in the partial information sessions is virtually identical to the main sessions. In Table 7 we replicate the game-level analysis of Table 1 adding the games from the partial

[41] 4 sessions with 3 groups of 6 players each, from the same population pool as above.

[42] Except that players have now 10 seconds to make a move.

information sessions.[43] The results are very similar to those reported in Table 2: the full information treatment has an effect on the number of links formed, the aggregate gains, and the number of rounds, but the partial information treatment is not statistically different from the control treatment. Other findings remain unchanged.

6 Concluding remarks

We design a laboratory experiment to investigate network formation in a market setting: in our game link formation is decentralized and players with fully heterogeneous payoffs can make offers and counter-offers, as in a Beckerian marriage model. The game is designed in such a way that if participants play a myopic best response, it reaches a stable equilibrium that does not depend on initial conditions. Our goal is to study how and why players in the lab depart from myopic best response.

We observe a high rate of convergence to the SPS equilibrium, in spite of the complexity of the experimental protocol. One possible interpretation is that competing for the best match is a strategic situation that is familiar to our subjects and for which they have good heuristics, probably such situations are ubiquitous in real-life situations (such as job market, housing market, public and private markets for procurement or health services). Also, we observe no loyalty towards randomly allocated links which are easily reshuffled, and we find that self-censoring speeds up the game significantly. We trace irrational decision mostly to two sources: the tendency of over-think in a setting where strategic thinking is not rewarding; and a 'once bitten twice shy' effect: players refuse offers from people who have been disloyal in the past, even though accepting them would be in their interest.

Many departures from rationality and self-interest have been studied in the lab. But very few experiments have focused on decentralized link formation, and none has introduced competition for mates. Our paper fills this gap and provides new insights on the determinants of behavior in decentralized matching games with competition. These insights should shed light on human behavior in a large class of market bargaining and

[43]We have 47 (instead of 48) of such games – one game from these sessions was subsequently discovered to have no SPS equilibrium, and it has been excluded from the analysis.

matching processes that arise in real life. This category of strategic games deserves more attention, and our experimental design provides a promising avenue to study them.

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Tables and Figures

Table 1: The treatment allocation scheme

	BLOCK 1					BLOCK 2			
	game 1	game2	game 3	game4		game 1	game2	game 3	game4
group: 1	A	B	***C***	***D***	13	A	***B***	***D***	C
group: 2	***B***	***C***	D	A	14	B	***C***	A	***D***
group: 3	***C***	D	A	***B***	15	C	***D***	***B***	A
group: 4	B	***A***	C	***D***	16	***B***	A	D	***C***
group: 5	***C***	***B***	D	A	17	C	***B***	*A*	D
group: 6	***D***	C	***A***	B	18	***D***	C	***B***	A
group: 7	C	***A***	***B***	D	19	C	***A***	***D***	B
group: 8	***D***	B	***C***	A	20	D	***B***	A	***C***
group: 9	***A***	D	B	***C***	21	***A***	***D***	C	B
group: 10	D	***A***	B	***C***	22	D	***A***	C	***B***
group: 11	***A***	C	***D***	B	23	A	C	***B***	***D***
group: 12	***B***	D	***A***	C	24	*B*	D	***C***	A

Notes: letter A indicates a game with empty initial configuration and no information, B indicates a game with empty initial configuration and full information, C indicates a game with complete initial configuration and no information and D indicates a game with complete initial configuration and full information. Underlined letters indicate unbalanced SPS configuration, letters in green indicate games with two SPS equilibria.

Table 2: Analysis of games

	(1) reach SPS	(2) % SPS links formed	(3) n. links formed	(4) tot. gains in lab	(5) n. rounds	(6) n. proposals accepted	(7) n. proposals rejected
T1 (2 initial links)	-0.021	-0.008	-0.021	0.833	0.250	-2.292	1.271
	(0.059)	(0.019)	(0.077)	(8.453)	(0.389)	(1.561)	(2.192)
T2 (full information)	-0.019	-0.009	0.136*	11.455*	-0.782*	-2.471	-6.873***
	(0.101)	(0.031)	(0.068)	(5.752)	(0.448)	(1.690)	(1.983)
T3 (unbalanced SPS)	-0.028	-0.008	-0.884***	-42.457***	-0.110	-1.354	3.721**
	(0.085)	(0.027)	(0.074)	(6.932)	(0.349)	(1.339)	(1.620)
T4 (double SPS)	0.084	0.018	-0.214	-15.540	0.489	3.212	3.599
	(0.234)	(0.048)	(0.144)	(13.795)	(1.174)	(5.286)	(5.366)
game n. 2	-0.043	0.014	0.124	-0.398	-0.886	-2.271	-4.543
	(0.122)	(0.036)	(0.119)	(10.891)	(0.551)	(1.771)	(2.685)
game n. 3	0.005	0.025	0.070	5.288	-0.058	0.940	-3.380
	(0.065)	(0.028)	(0.094)	(11.041)	(0.419)	(1.694)	(2.748)
game n. 4	-0.001	0.012	0.005	-11.352	-0.796	-0.640	-2.595
	(0.104)	(0.040)	(0.076)	(10.817)	(0.666)	(2.761)	(3.505)
group fixed effect	yes	yes	yes	yes	yes	yes	yes
session fixed effect	yes	yes	yes	yes	yes	yes	yes
Constant	1.043***	1.000***	5.835***	459.200***	5.006***	15.051***	19.570***
	(0.077)	(0.022)	(0.086)	(7.828)	(0.478)	(1.686)	(2.712)
Observations	96	96	96	96	96	96	96
R-squared	0.413	0.464	0.791	0.501	0.372	0.336	0.405

Robust standard errors in parentheses, clustered by group. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table 3: Analysis of links

VARIABLES	link
A_{ijg} (initial match)	0.016
	(0.017)
X_{ijg} (extreme match)	0.020
	(0.019)
SPS_{ijg}	0.934***
	(0.025)
T1 (2 initial links)	-0.008
	(0.010)
T2 (full information)	0.009**
	(0.004)
T3 (unbalanced SPS)	0.003
	(0.003)
T4 (double SPS)	-0.015*
	(0.008)
game n. 2	0.008
	(0.007)
game n. 3	0.005
	(0.005)
game n. 4	-0.000
	(0.005)
dyad fixed effect	yes
Constant	0.014**
	(0.006)
Observations	1,440
R-squared	0.873

Robust standard errors in parentheses, clustered by group. *** p<0.01, ** p<0.05, * p<0.1.

Table 4: Movers analysis

	(1) % violations	(2) status quo	(3) n. wishlist proposals	(4) 1st wishlist proposal
time on history	0.035	0.135	-0.585	-0.169
	(0.038)	(0.126)	(0.494)	(0.143)
time on payoffs	0.004**	-0.042***	0.159***	0.038***
	(0.001)	(0.004)	(0.011)	(0.004)
already 2 links	0.024***	0.206***	-1.322***	-0.132***
	(0.007)	(0.021)	(0.078)	(0.024)
T1 (2 initial links)	-0.002	-0.030	0.026	0.002
	(0.005)	(0.019)	(0.060)	(0.018)
T2 (full information)	-0.011	0.330***	-1.077***	-0.346***
	(0.007)	(0.033)	(0.096)	(0.032)
T3 (unbalanced SPS)	0.004	0.011	0.130*	0.014
	(0.006)	(0.018)	(0.063)	(0.026)
T4 (double SPS)	0.006	-0.031	-0.004	0.076
	(0.010)	(0.056)	(0.133)	(0.069)
round	-0.002	0.023**	-0.006	-0.039***
	(0.002)	(0.008)	(0.018)	(0.010)
game n. 2	-0.017*	-0.032	0.009	0.030
	(0.009)	(0.026)	(0.087)	(0.033)
game n. 3	-0.017**	-0.040	-0.066	0.035
	(0.008)	(0.026)	(0.095)	(0.031)
game n. 4	-0.019**	-0.038	0.118	0.036
	(0.008)	(0.032)	(0.088)	(0.035)
session fixed effects	yes	yes	yes	yes
player fixed effects	yes	yes	yes	yes
Constant	0.056***	0.102**	1.958***	0.828***
	(0.009)	(0.039)	(0.076)	(0.042)
Observations	1,980	1,379	1,379	1,379
R-squared	0.155	0.388	0.550	0.373

Robust standard errors in parentheses, clustered by group.

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

Table 5: Movers analysis (history of play)

	(1)	(2)	(3)	(4)
	payoff-increasing offers		payoff-decreasing offers	
previous refusal	-0.041		0.037	
	(0.029)		(0.035)	
previous severance		0.019		0.001
		(0.028)		(0.019)
gain	0.012***	0.012***	0.000	0.001
	(0.001)	(0.001)	(0.000)	(0.000)
T1 (2 initial links)	0.038*	0.034	-0.003	-0.003
	(0.019)	(0.020)	(0.005)	(0.005)
T2 (full information)	-0.137***	-0.135***	-0.002	-0.002
	(0.021)	(0.021)	(0.005)	(0.005)
T3 (unbalanced SPS)	0.067**	0.066**	-0.002	-0.003
	(0.025)	(0.025)	(0.005)	(0.005)
T4 (double SPS)	0.024	0.026	-0.004	-0.006
	(0.036)	(0.036)	(0.006)	(0.006)
round	-0.009	-0.017***	0.000	0.001
	(0.007)	(0.006)	(0.002)	(0.002)
game n. 2	-0.005	-0.007	-0.013*	-0.014*
	(0.024)	(0.023)	(0.007)	(0.007)
game n. 3	-0.004	-0.003	-0.010	-0.011
	(0.030)	(0.030)	(0.008)	(0.008)
game n. 4	0.036	0.036	-0.002	-0.003
	(0.027)	(0.027)	(0.008)	(0.007)
session fixed effects	yes	yes	yes	yes
player fixed effects	yes	yes	yes	yes
Constant	0.020	0.038	0.038***	0.035**
	(0.041)	(0.036)	(0.012)	(0.013)
Observations	3,871	3,871	2,819	2,819
R-squared	0.244	0.244	0.129	0.126

Robust standard errors in parentheses, clustered by group.

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

Table 6: Respondents analysis

	(1)	(2)	(3)	(4)
	Violation of myopic best response			
gains	-0.002*	-0.001*	-0.002**	-0.002**
	(0.001)	(0.001)	(0.001)	(0.001)
time on history		0.002		
		(0.003)		
time on payoffs		0.008***		
		(0.003)		
previous refusal			0.058*	
			(0.033)	
previous severance				0.055*
				(0.031)
T1 (2 initial links)	-0.004	-0.002	-0.006	-0.007
	(0.011)	(0.012)	(0.011)	(0.011)
T2 (full information)	0.019*	-0.021	0.020*	0.020*
	(0.010)	(0.015)	(0.010)	(0.010)
T3 (unbalanced SPS)	-0.012	-0.015	-0.011	-0.010
	(0.010)	(0.010)	(0.010)	(0.010)
T4 (double SPS)	0.032	0.028	0.031	0.032
	(0.022)	(0.021)	(0.021)	(0.021)
round	-0.007	-0.005	-0.008	-0.009*
	(0.005)	(0.005)	(0.005)	(0.005)
game n. 2	0.006	0.007	0.006	0.005
	(0.017)	(0.017)	(0.017)	(0.017)
game n. 3	0.007	0.008	0.007	0.006
	(0.014)	(0.015)	(0.014)	(0.014)
game n. 4	-0.005	-0.001	-0.005	-0.006
	(0.014)	(0.014)	(0.014)	(0.014)
session fixed effects	yes	yes	yes	yes
player fixed effects	yes	yes	yes	yes
Constant	0.150***	0.143***	0.157***	0.159***
	(0.028)	(0.030)	(0.029)	(0.029)
Observations	2,305	2,305	2,305	2,305
R-squared	0.162	0.168	0.164	0.164

Robust standard errors in parentheses, clustered by group.

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

Table 7: game-level analysis, partial vs. full information

	(1) reach SPS	(2) % SPS links formed	(3) n. links formed	(4) tot gains in lab	(5) n. rounds	(6) n. proposals accepted	(7) n. proposals refused
T1 (2 initial links)	-0.072	-0.032	-0.023	-2.768	0.318	-2.065*	2.047
	(0.049)	(0.019)	(0.059)	(6.540)	(0.296)	(1.095)	(1.730)
T2 (full information)	-0.020	-0.010	0.136*	11.291*	-0.789*	-2.516	-6.782***
	(0.102)	(0.031)	(0.071)	(6.031)	(0.455)	(1.675)	(1.995)
T2 (partial information)	-0.091	-0.024	-0.030	-2.812	-0.214	0.121	-4.558
	(0.099)	(0.035)	(0.084)	(7.446)	(0.843)	(2.287)	(5.826)
T3 (unbalanced SPS)	-0.013	-0.002	-0.877***	-40.486***	-0.028	-0.802	2.639
	(0.062)	(0.021)	(0.058)	(5.278)	(0.348)	(1.102)	(1.984)
T4 (double SPS)	-0.016	-0.020	-0.198	-19.123*	0.305	3.270	0.603
	(0.187)	(0.053)	(0.120)	(10.394)	(0.857)	(3.823)	(4.151)
game n. 2	-0.054	-0.001	0.044	-6.462	-0.553	-1.522	-1.300
	(0.110)	(0.036)	(0.095)	(8.016)	(0.455)	(1.371)	(2.537)
game n. 3	-0.001	0.018	0.045	3.382	0.406	1.848	0.422
	(0.071)	(0.028)	(0.076)	(8.297)	(0.465)	(1.435)	(3.095)
game n. 4	0.031	0.021	-0.048	-15.806*	-0.250	0.163	0.686
	(0.074)	(0.028)	(0.065)	(9.079)	(0.522)	(1.950)	(3.221)
group fixed effect	yes	yes	yes	yes	yes	yes	yes
session fixed effect	yes	yes	yes	yes	yes	yes	yes
Constant	1.098***	1.024***	6.004***	442.536***	2.235***	6.184***	10.333**
	(0.086)	(0.035)	(0.079)	(7.590)	(0.596)	(1.942)	(4.127)
Observations	143	143	143	143	143	143	143
R-squared	0.424	0.429	0.774	0.497	0.416	0.376	0.396

Robust standard errors in parentheses, clustered by group. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Appendix A: Computer interface and information

We provide here a detailed description of the computer interface. All the information relative to the game is presented to each player in the form of an hexagon with the six corners representing the six players in the group. An example of this screen is presented in Figure A1 below. The player always sees himself at the bottom of the hexagon, associated with his identification letter in the game (letter F in figure A1). In Figure A1, it's F's turn to play and he can decide whether to propose a link to any other player or pass his turn. The other five players are distributed on the other five corners, each with his letter. Within a game this configuration does not change. Next to player j, player A sees π_{Aj}, the payoff associated with linking to that player. Depending on the treatment, he may also see information about the payoffs vector of each other player – more about this was said in Section 3.2.

The links that all players are currently holding are represented graphically on the screen as black lines linking two players. The network that all players see changes in real time each time a link is added or dropped. The screen also reports in real time the current state of the game, *i.e.*, the game number (from 1 to 4), the round number (from 1 to 8), which player's turn it is (the mover's letter is highlighted in green), and the time left to make a decision – see Figure A1. Furthermore, the background color of the screen changes to red when the player is called to take an action (either when it is his turn, or when he receives an offer).

When it's a player turn, he can make decisions of three kinds: sever a link, propose a link, and terminate the turn. If he decides to make an offer to another player, a blue dotted line appears on the screen (visible to himself and the offered player only). Figure A3 depicts player F (who holds no link) who has made an offer to A and is waiting for a response. In case the mover is already holding two other links, one of those must be deleted if the new offer is accepted, and this information is also depicted graphically on the screen: the two links appear in red and the mover is asked to select the link to delete in case the new offer is accepted, which then turns into a red dotted line. Figure A4 represents player B who holds links to C and A, and has proposed a link to F – he's ready to delete his link with C if the offer to F is accepted. In the moment depicted in Figure A4, B is waiting for F's response. If the offer is accepted, the blue dotted line turns into a black continuous line, and the red dotted line disappears. This new configuration becomes visible to all players (Figure A5). Within his turn the mover can also decide to sever a link – Figure A6 represents player D about to confirm the deletion of his link with player E.

Similarly, when a respondent receives a linking offer, a dotted line from the offering player appears on his screen. Figure A7 depicts player B receiving an offer from D. Since player B already holds two links, he is asked to select one link to delete (Figure A8). Upon his choice, the offered link will be considered accepted and turns into a continuous black line while the link selected for deletion disappears. Changes resulting from accepted offers become immediately visible to all players in the group, whether it is their turn or not.

A player can never see information on linking offers that do not involve him directly. So if player i is offering to link with j, this is only visible to players i and j - the new link will eventually become visible to everyone if the offer is accepted. Moreover, another player, say k, does not see that player i to whom he is currently linked is intentioned to drop this link if his linking offer to another player j is accepted. This feature is intended to mimic the functioning of real-life markets where an agent observes the offers he makes and receives, but does not typically observe offers between other players before they are accepted.

At any time during a game, players can browse through the entire history of the current game. This history appears on the left-side of the screen in a separate dedicated window (Figure A9). However the history is only visible if the player requests so by clicking on the left side of the screen - by default, the left side is empty (figures A1-A8). The history of the game can be visualized in two different ways: by round, or by turn. All the retrospective information that was available to a player during the game (including the order of the unaccepted offers he has made) is made available to him. Figure A9 illustrates the following situation: during turn number 4 (of game 3, round 1), player E (at the bottom of the hexagon) is browsing the history of turn 1.

Since the game is rather intricate, each experimental session begins with a period of time during which participants are invited to read the written instructions (reproduced in Appendix B). At the end of this reading period, participants are given a PowerPoint presentation followed by question time. To avoid strategical behavior at the end of the experiment, players are informed that they would have to wait for all groups to complete their last game before they could leave the laboratory. After this presentation, participants play a training session lasting approximately 20 minutes to familiarize themselves with the game and the different screens. The training session is the same for all participants, and is designed to illustrate all the main features of the game as well as the different treatments.

Figure A1

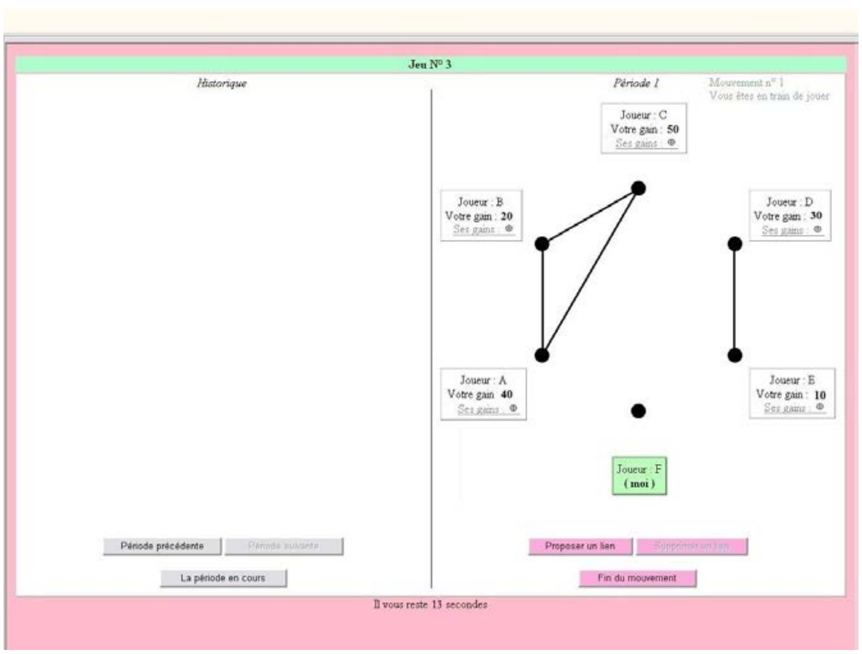


Figure A2

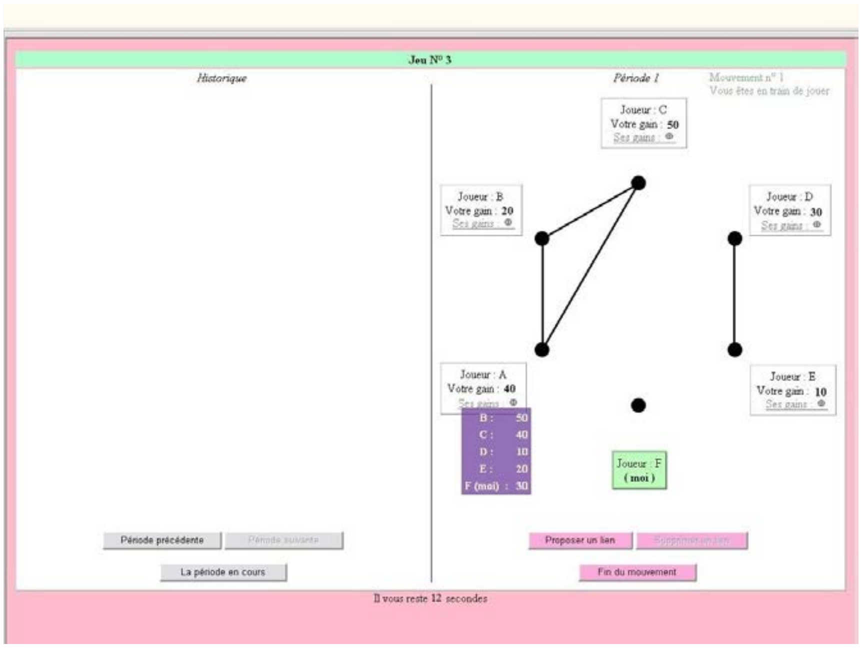


Figure A3

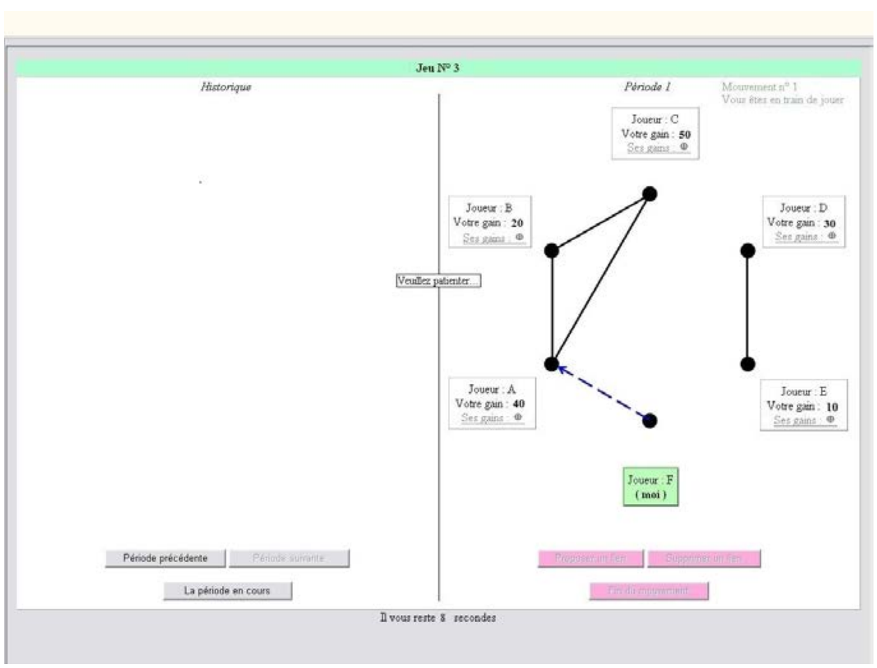


Figure A4

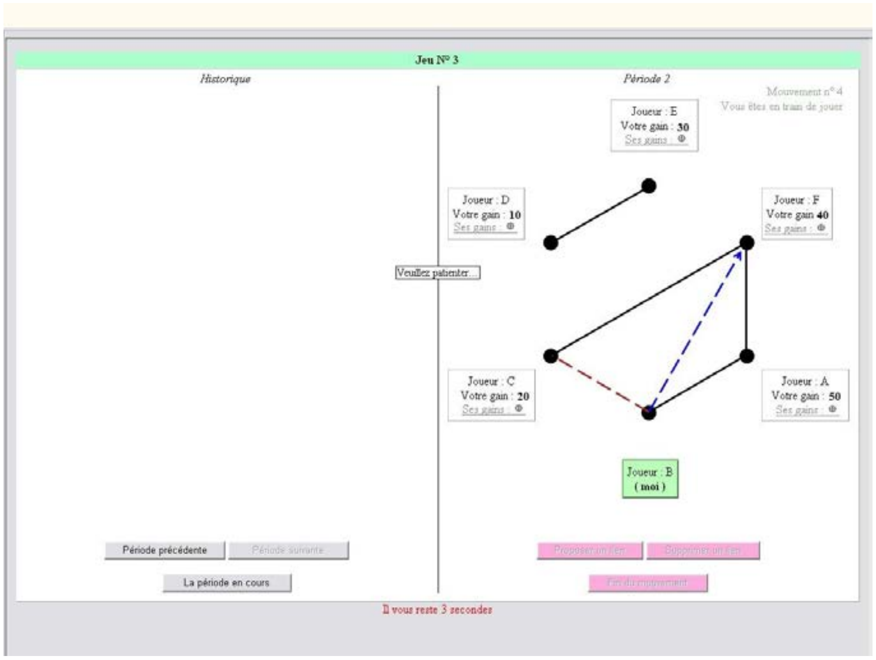


Figure A5

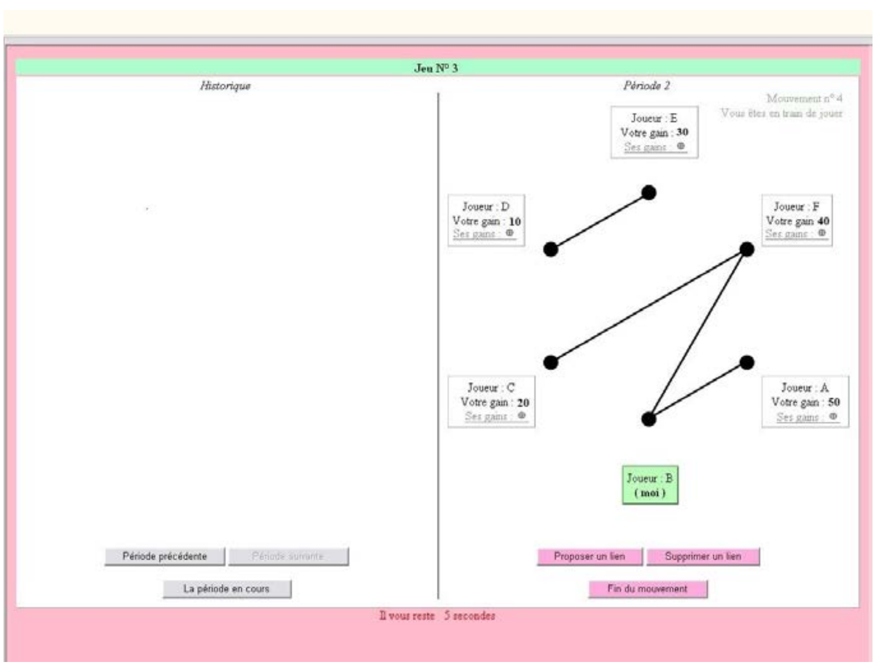


Figure A6

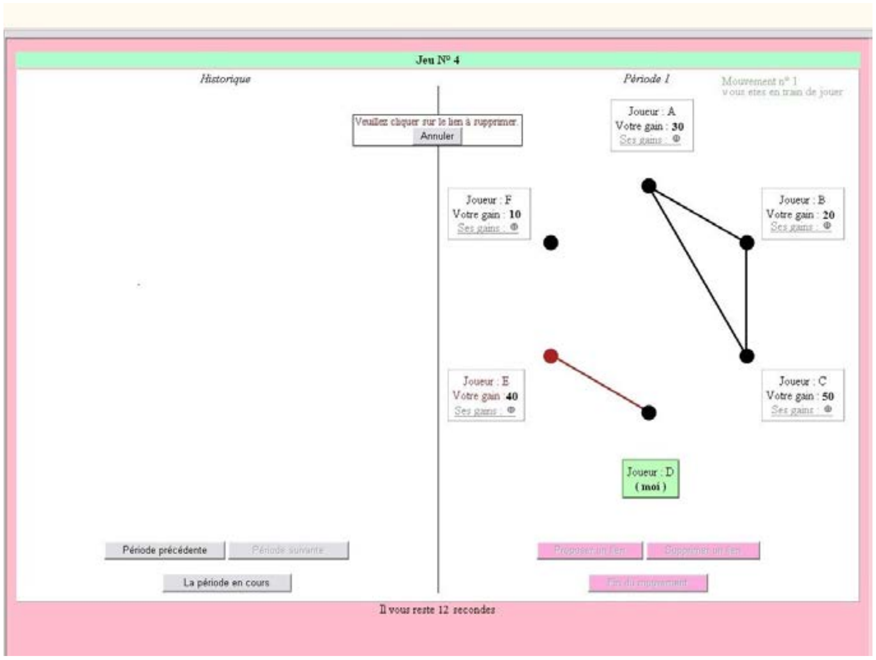


Figure A7

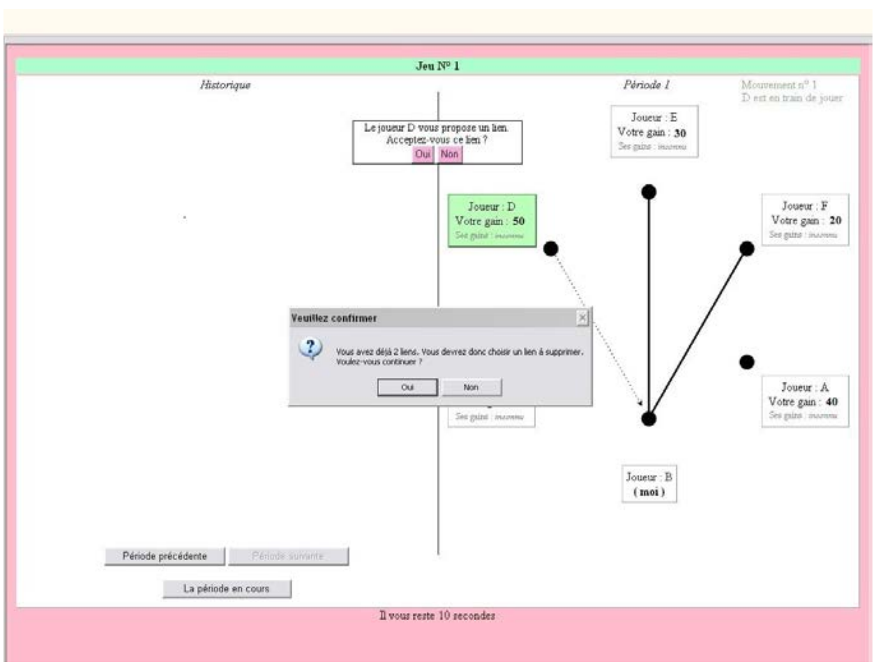


Figure A8

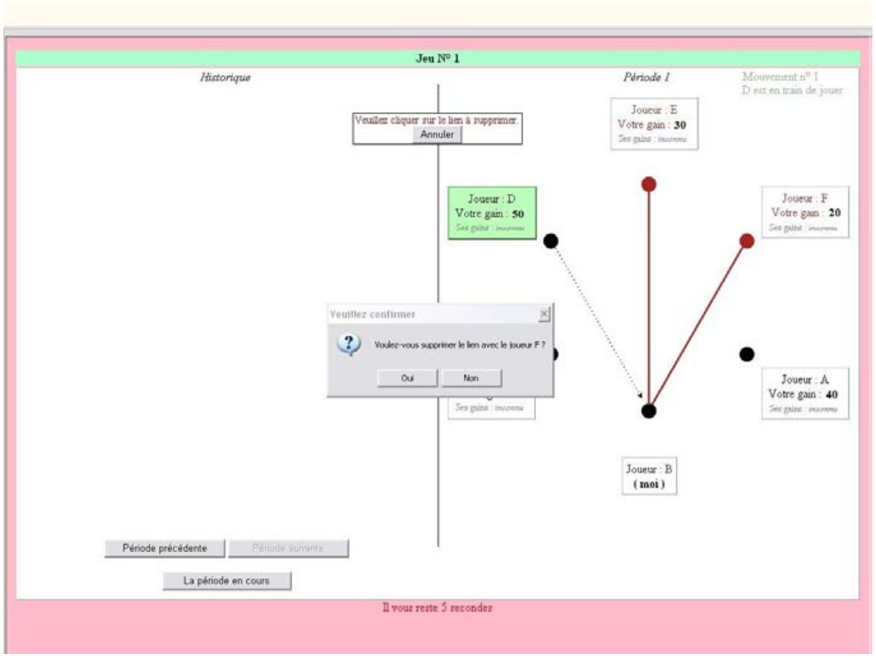
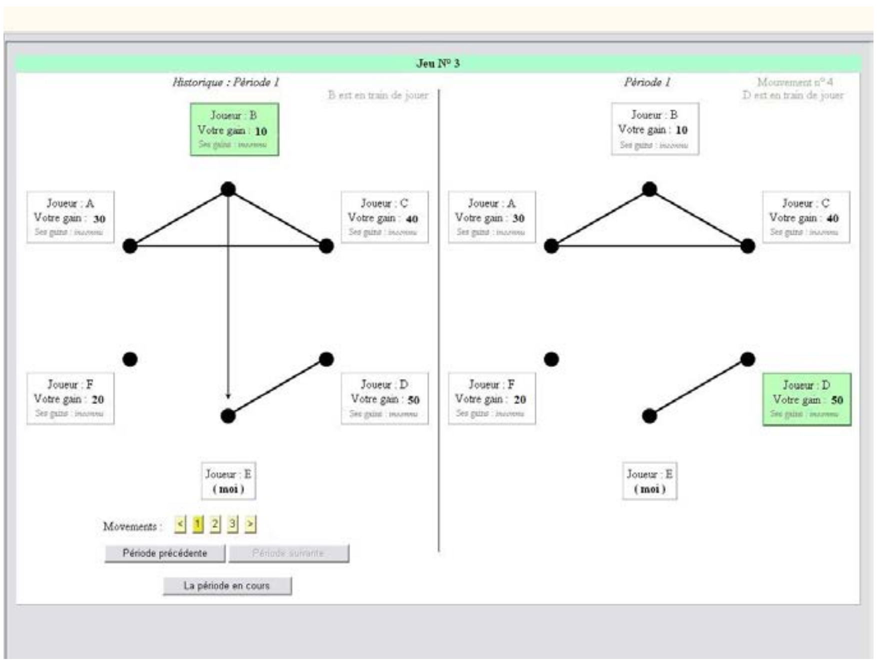


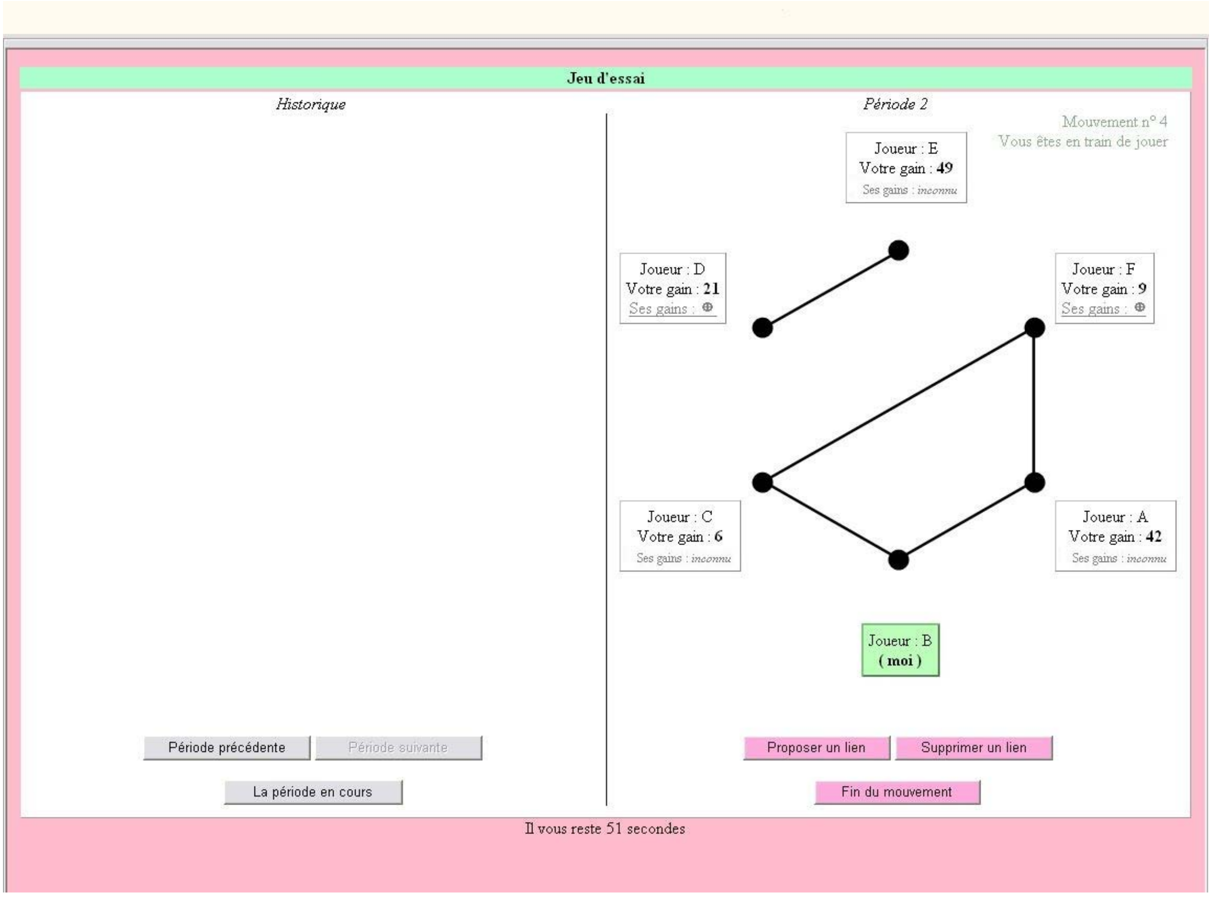
Figure A9



APPENDIX B: DESCRIPTION OF THE GAME

Welcome to the laboratory! Today you are going to play a game whose rules are explained in what follows.

Example of screen



General setting

There are 6 players, visually located around a circle and labelled with letters (A, B, C, D, E, F). You are the player located at the bottom of the circle: your icon is indicated by "ME" plus your identifying letter (in the example above you are player B). Existing links are indicated with a tick black line.

This is a link formation game where links are formed by mutual consent:

- Each player can have up to 2 links at each moment of the game (but it is always possible to have one link or no links);
- During the game, players have the opportunity to delete existing links and/or create new links among them.

The gains

"your gain": below the name of other players you can see a label "your gain" indicating a numerical value. The total gain of a game is for you the sum of your gains for all players linked with you at the end of the game. For instance, if the configuration of the image above was the final configuration of the game, your total gain of the game would be 6+42=48 points.

“his gains”: sometimes (but not always) you can also see “his gains”, that is, the gains of other players for the links that they can possibly form. When you see the symbol below a player’s name it means that you can browse his gains: just put your mouse on this symbol, and a window with this information will appear.

For instance, in the figure above you can see “his gains” for player D. In order to browse this information, go with your mouse on and you will see:

Thus, if you form a link with D you get a gain of 21 and he gets a gain of 17.

- Note that gains are player-specific. This means that if D is worth 21 for you, it does not mean that he is worth 21 for the others!

Your final payoff is given by the sum of the values of people you are linked to at the end of the session. Your goal is therefore to end the session with the most profitable links you can form (keeping in mind that you can form up to 2 links, but you may also end up with 1 link or none). If the configuration in the picture above was the configuration of the end of the game, Player F (“ME”) would get a payoff of 3+5=8.

<u>The game</u>

The game is organized in several rounds:

- At round 0 the game starts from a given network configuration;
- In each round all 6 players have the turn to form and/or sever links;
- the order of move changes at each round (for instance, you can be the first to move in round 2, and the 4th to move in round 3).

The game ends:

- At the end of the 8th round,
- Before the 8th round, if for one entire round no new link is created and no existing link is severed.

<u>The screen</u>

At each moment of the game on the right of the screen you see:

- The existing links (indicated with a tick black line);
- The offers that you make or you receive (indicated with a dotter arrow);
- The player who is moving in this turn (his name appears in green);

If you click on the left of the screen you can browse back and re-see the history of all past rounds (in a way we will explain later on).

When you are called to do an action (because it is your turn to move or because you are called to accept/reject an offer) the background colour of your screen becomes red to capture your attention.

The actions

When it's your turn to move, three buttons appear in front of you: "propose a link", "delete a link", "end of move".

You can:

- Make offers to all players to which you are currently not linked to, if you wish (but keep in mind that you cannot have more than 2 links at each moment of the game: if your offer is accepted, you may need to cut an existing link);
- Cut one of both the links you hold, if you wish.

You can use the buttons "propose a link" and "delete a link":

- As many times as you want, subject to the constraints above (in the example of the figure you can cut the link with C and/or A, and you can propose a link to one of more of the following players: D, E or F);
- In the order of your choice (for instance you can first propose a link to D, then you cut a link with A, and later on propose a link to F);
- If you change your mind you can get back to the main screen or press the button "end of move".

You have 15 seconds max to make your choice. If you do not press any button within 15 seconds, your turn will end.

1. Button "propose a link":

   By pressing the "propose a link" button and then clicking on a player's icon, you can propose a link to a node. Only the icons of the nodes to which you are not linked are active.

   - If you have currently less than 2 links: when you propose a link to a certain player (for example player D), the screen will display "invitation to D sent" and will send D the notification of your offer.
   - If you have currently already 2 links: when you propose a link to a certain player (for example player D), the program will open a window showing the list of you current partners (C and A) asking "which link do you want to delete, if D accepts your offer?" Once you have decided which link you want to cut, the program will display "invitation to D sent" and will send D the notification of the offer. Note that the old link will be cut only in case the new link is accepted!

     The other player shall accept or refuse your offer: In both cases, the player to which you want to link (D in this case) receives a notification, and he must make the current choice:

- If D has currently less than 2 links: he has to decide whether to accept or not your offer.
- If D has already 2 links: he has to decide whether to accept or not your offer, and if he presses YES the program will show him a list of his current partners and asks him "which link do you want to delete"?
- If D does not press any button within 15 seconds, the offer is considered as refused.

<u>If the offer is accepted, the network configuration changes and the new link appears:</u> When D has decided whether to accept or reject the offer You are notified of his decision (a window displays "offer accepted" or "offer rejected"). If the offer is accepted, the network configuration changes: the new link appears on the screen in a solid black line, and the deleted links disappear (these changes are visible to all players).

2. Button "delete a link":
   By pressing it and then click on the icon of a player to which you are currently linked, you can arbitrarily delete a link of your choice (and have it disappear from the screen). Yu do not need the consent of a player to delete the link with him.

3. Button "end of move": once you are done with the two buttons "propose a link" and "delete a link" you can click on "end of move"

<u>The history</u>

If you click on the buttons at the left of the screen, you can browse the history of the ongoing game:

- You can navigate by round and by move,
- You always see: the initial configuration, who was in charge of moving, the links formed/deleted, the propositions of links to you;
- If it was your turn to move, you can also see ther propositions that you made and were not accepted.

<u>Today</u>

Today you will start with a training game (to get used to the software). After that, you will play 4 games.

At the end of each game, the identity of the players with whom you are playing will stay the same but the letters will be reshuffled. This means:

- You may be called D during the first game, and A during the second game
- You never know how the other players have changed position (the person named C during the first game may be called D during the second game)

<u>Your final payment</u>

Each game will have his final gain (which is the sum of the values of "your gain" for the players you are linked to at the end of the game, as explained above). At the end of the session, the computer will randomize one of these 4 games, and your final payment will be based on the final gain of this game. The gain of the training game will not be considered.

The payment rule is the following: 6 euros fixed + 0.2 euros for each point.

In order to be paid and leave the laboratory, you need to wait (in silence) until we call you.

Now you will attend a PowerPoint presentation in order to clarify further the rules of the game. All questions are welcome.