An Experimental Study on Decentralized Networked Markets*

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Abstract

We design a laboratory experiment to investigate matching in a decentralized market of deferred acceptance. Agents are undifferentiated and may have multiple partners; their payoff depends on who they match with. The experiment is designed in such a way that a stable configuration exists, but cannot be eyeballed by the participants due to the computational complexity of the game. In spite of this, subjects are remarkably good at reaching a stable match, even when the payoffs of others are not publicly observed. More information does, however, speed up convergence thanks to self-censoring. We trace irrational matching choices mostly to two sources: the tendency of over-think in a setting where strategic thinking is not necessary, and the reluctance to accept matching offers from those who have been disloyal in the past.

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1 Introduction

Stable matching theory has inspired several market design experiments, such as the assignment of medical interns to hospitals (Roth and Peranson 1999), students to schools (Abdulkadiroğlu *et al.* 2005), and transplantable kidneys to patients (Roth, Sönmez and Ünver 2005*a,b*). In all these applications the solution is centralized, *i.e.*, the preferences of participants over potential partners are first elicited, and then a central clearinghouse applies an algorithm that yields a stable match. Two types of difficulties arise in this framework. First, the algorithm may yield multiple stable matches or no stable match – both of which create problems for the clearinghouse.[1] The second difficulty arises when participants cannot costlessly rank all potential partners. As a result, they typically provide a truncated ranking, either by design or by choice. This is known to distort the truthful revelation of preference rankings, *e.g.*, naive participants only list their top choices while sophisticated participants strategically influence match selection.[2] To avoid these shortcomings, we focus instead on a decentralized market with deferred acceptance. Decentralized markets do not require ex ante preference revelation. But if deferred acceptance is not enforced, it is often in the interest of some agents to make explosive offers, which leads to unraveling (*e.g.*, Kagel and Roth 2000). These features have been documented in numerous real markets (*e.g.*, Roth 2016) and have been shown to arise experimentally (Kubler *et al.* 2016).

In this paper we set up a decentralized market with enforced deferred acceptance and we study, not in theory but in practice, whether the sequencing of offers and counteroffers leads to a stable match. There are two general motivations for this experimental design. First, there are many behavioral reasons why individuals may adopt strategies that do not lead to a stable outcome: for instance, they may show inertia and stick

[1]For instance, in one-to-one two-sided markets, it is well known that multiple equilibria arise due to the presence of ties. In this case, who gains the most from the match depends on which side (*i.e.*, bride or groom) makes offers. This enables the algorithm operator to affect the distribution of welfare gains across market participants.

[2]See Calsamiglia, Haeringer and Klijn (2010) who investigate preference manipulation when subjects have to submit a limited number of options in a school choice mechanism. In a more distant vein, Roth (1991) and Chen and Sonmez (2006) discuss strategic preference manipulation when subjects can submit a full list of their preferences.

to early acceptances; they may stop making offers too early; they may seek to prevent stable matches for selfish or invidious reasons; or they may form inefficient links for altruistic reasons. If decentralized matching with deferred acceptance is unable to reach a stable match, this may justify favoring centralizing matching despite its limitations. Our second motivation is that it has now become conceivable to implement decentralized markets with deferred acceptance online. We therefore would like to know how close such structured markets can get to a stable match in situation where we know what the stable match is.

The experimental literature on decentralized matching is not large.[3] Our experimental design is conceptually closest to the paper by Echenique and Yariv (2013), with three important differences. First, they study a one-to-one two-sided matching problem inspired of the Beckerian marriage market; we study a many-to-many one-sided matching problem aimed at representing a networked market for collaboration or exchange. Despite the pervasiveness of real-life examples of decentralized networked markets, the topic has received little attention from economists. Such a general matching framework is more complex to solve for a stable match than a marriage-market setting, and has never been approached experimentally. Second, while Echenique and Yariv (2013) impose complete information regarding other participants' preferences, we exogenously vary the amount of revealed information. This leads us to conclude that preference revelation is not crucial for the market to reach stability. Third, while Echenique and Yariv (2013) focus on equilibrium selection, we study the individual motivations that may lead players to make choices that are irrational from a payoff-maximization perspective.

We set up an intuitive protocol for market interactions where participants are free to make and accept offers in a sequential and fairly unconstrained manner. This approach has similarities to, say, an auction or a stock market floor, in the sense that the action space and sequence of actions are regulated. But, within those constraints, the mechanism is decentralized and interactive and is fashioned along the lines of a

[3]See Nalbantian and Schotter 1995; Kagel and Roth 2000; McKinney, Niederle and Roth 2005; Ünver 2005; Eriksson and Strimling, 2009; Niederle and Roth 2009; Pais, Pintér, and Veszteg 2012; Echenique and Yariv 2013.

Gale-Shapley matching algorithm. Formally, subjects are asked to match with up to two other experimental subjects. The game is organized as a sequence of rounds in which subjects take turns in making offers to other subjects, who can accept or reject them. In contrast to matching games that iterate on links (*e.g.*, Carillo and Gaduh 2016), we iterate on players who, like in a game of monopoly, can take several actions when it is their turn. The game stops when an entire round occurs without any change in held offers.

When their turn comes, agents who already hold two partners can make a new offer, but if the new offer is accepted they must drop one of their previously accepted links. The same principle holds when accepting an offer: subjects can never hold more than two partners and thus, if they already have two links, they must drop one of these two links if they want to accept a new offer. Gains are determined by the matches subjects hold when the game ends.[4] Payoffs are pair-specific, that is, fully heterogeneous across players and across matches.[5] Because of tractability issues, a payoff structure of this kind has been rarely investigated in theory and, to the best of our knowledge, never experimentally. In our game the existence and number of stable matches is entirely and uniquely determined by the payoff matrix. We only retain payoff matrices that allow (at least one) stable configuration and discard those that have no stable match.[6]

The first objective of the paper is to see whether subjects converge to a stable match. By structuring the decentralized market along the lines of a Gale-Shapley matching algorithm, we ensure that in our context if subjects follow myopic rational play, convergence to a stable match is guaranteed. Whether this is indeed the case

[4] In this paper only direct partners affect individual payoffs – *i.e.*, there are no externalities across subjects generated by the matching pattern. In addition, subjects cannot negotiate over price, a feature common to much of the matching literature. For experiments on bargaining in networks see Charness, Corominas-Bosch and Frechette (2007), and Agranov and Elliott (2016).

[5] This payoff structure mimics the interaction of common preferences and homophyly, which are believed to be the two main forces behind matching processes in real-life contexts. This can easily be shown 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 preference), each pair of player is assigned a relational parameter d_{ij} representing their socioeconomic distance (homophyly), and the payoff of i from matching with j is $q_j - d_{ij}$.

[6] The number of stable matches (as well as their characteristics) is verified by enumeration – see Sections 2.4 and 3.3 for details.

in practice needs to be demonstrated experimentally. There are indeed many reasons why subjects may deviate from myopic rational play – *e.g.*, they may seek to outsmart others, or they may pursue objectives other than the maximization of their own payoff. Since the experimental design allows us to track all offers and acceptances, the second objective is to identify behavioral patterns that may lead subjects away from a stable match. In order to shed light on this second point we introduce four treatments testing different hypotheses regarding the role of information and frictions in decentralized markets of deferred acceptance.

In the first and most important treatment we provide full information about other players' payoffs. This stands in contrast to the control experiment where subjects only observe their own payoff vector. Complete information is a rather implausible assumption for both the coordination and the cognitive capacity it requires, even more so in a complicated matching game like ours. The theoretical literature on two-sided decentralized markets has claimed that complete information is necessary to attain stability (Haeringer and Wooders 2011; Niederle and Yariv 2011), while some empirical evidence suggests that lack of information *per se* in not enough to drive two-sided markets away from stability (Pais, Pintér, and Veszteg 2012). In our context the role of full information is *a priori* unclear. On one hand, full information may speed up convergence if better informed subjects refrain from making offers that are doomed to be rejected. On the other hand, within the time constraint of the experiment, it is impossible for subjects to pin down the stable configuration even when information is fully disclosed. Consequently, full information may just confuse players and even drive them away from the stable match.

Three other experimental treatments are introduced, representing market frictions which may play a role in networked markets. In the second treatment we allocate subjects two randomly assigned partners at the beginning of the game. Subjects in the control experiments begin with no partner. This initial configuration does not affect what the stable match is, since it is fully determined by the payoff matrix. However, if subjects display inertia or loyalty to existing partners, we expect a lower rate of convergence to stability when subjects start the game with randomly assigned partners. In the third treatment we introduce so-called unbalanced games where the stable match includes players with less than two links. If play is affected by fairness considerations (*e.g.*, Fehr and Schmidt 1999, Blanchflower and Oswaldt 2004), players may seek to 'co-opt' these unfortunate players, thereby reducing the rate of convergence to a stable match. In the fourth treatment, we investigate the issue of multiple equilibria which has been a key preoccupation for matching theorists. In particular, we study whether difficulties arise when the game admits two stable matches – *e.g.*, because of coordination failure.

We find that experimental subjects reach a stable match in 86% of the games. This is remarkably high, and virtually identical to the 85% rate reported by Echenique and Yariv (2013) for a marriage market with full information, even though our setting is more complex. Furthermore, even when a stable configuration is not reached, most realized links belong to a stable match even if some of them do not. Match stability thus predicts the overwhelming majority of realized links in spite of the fact that the complex nature of the game makes it impossible for subjects to calculate the stable match. We also find that information on others' payoffs speeds up convergence *via* self-censoring, but it is not essential for reaching a stable match: players overcome their lack of information by experimenting with offers and counter-offers. We find little or no evidence that play is affected by inertia or other-regarding preferences (altruistic or invidious), but some observed behavior is consistent with a satisficing heuristic. Irrational matching choices seem driven by two main factors. The first one is a tendency to over-think: players attempt to act strategically in a setting that does not require either strategy or coordination – myopic rational play is guaranteed to reach a stable match. Secondly, players seem to condition their offers and acceptances on past play, *i.e.,* they seem reluctant to match with players who have rejected them before, even when doing so is in their material interest.

The paper contributes to the existing literature in several ways. First, our experimental results contribute to the matching literature by confirming that decentralized markets of deferred acceptance have a strong tendency to converge to a stable match, even with no information about others' preferences. Information has been regarded as crucial by matching theorists (Haeringer and Wooders 2011; Niederle and Yariv 2011); our findings show that subjects can circumvent the lack on information by experimenting with competitive offers. Secondly, we contribute to the growing experimental literature on network formation.[7] Only a few experimental papers have dealt with bilateral link formation, perhaps because of the issue of equilibrium selection (Deck and Johnson 2004; Di Cagno and Sciubba 2008; Burger and Buskens 2009; Conte, Di Cagno and Sciubba 2009). Out of those, only two papers explicitly focus on stability (Carrillo and Gaduh 2012; Kirchsteiger *et al.* 2016).[8] Both take pairwise stability as equilibrium concept, which only requires links to be robust to individual deviations (Jackson and Wolinsky, 1996).[9] The stability concept we adopt borrows from the matching literature in that it allows for two-players deviations. In addition to its predictive power demonstrated by our experiment, this concept has several theoretical advantages: it dramatically decreases the set of equilibria relative to pairwise stability,[10] while only considering deviations that require minimal coordination without the need for farsightedness (Kirchsteiger *et al.* 2016); and it naturally suits competition for partners in decentralized markets. In the theoretical literature on network, this equilibrium concept has been called 'strong pairwise stability' by Belleflamme and Bloch (2004). In this paper we use the term 'stable match' or 'stable configuration' for a network configuration that is stable in the sense of the matching literature and strong pairwise stable is the sense of Belleflamme and Bloch (2004).

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

[7] 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.

[8] Kirchsteiger *et al.* (2016) incorporate an element of farsightedness into the notion of stability 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 equilibria respectively.

[9] To satisfy pairwise stability, an equilibrium shall contain only and all the links that are beneficial to both parties involved.

[10] In our game, any configuration with two links per player is a pairwise stable configuration.

2 Experimental design

We design an decentralized and sequential matching protocol that has three key features: (1) deferred acceptance is externally enforced; (2) at no point of the game players can 'hold' more than their allowed number of links; and (3) the sequencing of offers and acceptances is orderly and fair-handed, as in a board game. We implement this protocol with a player interface specifically designed to be visual and intuitive. As will become apparent later, this interface is simple and can easily be generalized to other settings – including real life matching applications. The main research question is whether, in this specific gaming environment, players can reach a stable match.

2.1 The game

Participants play a sequence of four games together. Each game is a decentralized matching game with deferred acceptance organized along the lines of a Gale-Shapley matching algorithm. The purpose of the game is for each player to form two links so as to maximize their payoff. To this effect, players make linking offers to each other. If an offer is accepted, it is 'held' by both players as part of their prospective links. The process of offers and counteroffers takes place over time in an interactive and sequential manner. When accepted links no longer change, the game stops and payoffs are calculated based on the links held at the end of the game. This mechanism enforces differed acceptance and prevents unraveling.

Formally, each game is divided into a sequence of up to 8 rounds. Within a round, each player gets his turn to play – as in a board game except that the order of players within a round changes randomly across rounds.[11] When his turn comes, the selected player is allowed to make offers to each of the other players, one at a time. Each of these offers is in turn either rejected or accepted, although acceptance is not immediately binding. At each moment of the game, a player can only hold a maximum of two links.

[11] Randomization within rounds is reminiscent of a random serial dictator design, the benefit of which is to break ties and to ensure convergence to a single stable outcome. It offers the same advantage here, *i.e.*, to potentially break indeterminacy in the presence of multiple stable matches. Re-randomization across rounds is used to reduce the risk of cycles.

When the game ends, acceptances become final and the set of matches determines the players' gain for that game. More details are presented below.

The main advantage of this game 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 a matching process that allows a natural form of interaction increases the likelihood that our experiment brings to light behavior patterns that are predictive outside the lab. Much care was also devoted to creating a computer interface that is both informative and intuitive for players.

In what follows we start by describing the practical conditions under which the experiment was held and we introduce the details of the protocol.

2.2 The protocol

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.[12] Each game follows the sequence of rounds and turns described above. Within a round, each player gets his turn to play and the order of players changes randomly across rounds. The game ends when the network configuration remains unchanged for one entire round (*i.e.*, 6 turns with no change). Put differently, during this last round each player had the opportunity to drop links – but did not – and could make offers – but if he did, they were not accepted. This gives players a last opportunity to undo previous mistakes. In a Gale-Shapley algorithm, a weakly dominant strategy is for players to always make all the offers that dominate the links they currently hold. We did not want to discourage this strategy since it ensures convergence to a stable

[12]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.

match. The stopping rule nonetheless implies that nobody can prevent convergence by indefinitely making offers. The game also stops at the end of the 8^{th} round, whichever happens first. This feature eliminates the possibility of endless cycling.[13]

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 from another player. 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 make an offer to another player he's currently 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 links to two other players and makes a new offer, he must specify which existing link he is willing to drop in case the offer is accepted.[14]

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 same 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.[15] 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

[13] In practice, this limit is very rarely binding, and we observe that convergence is very quick in the large majority of cases: out of the 96 games in the main sample, 36 games converged already by the 2^{nd} round, 79 games converged by the 4^{th} round, and only 5 games reached the 8^{th} round without having converged.

[14] For instance, if mover A already has two partners B and C, and makes an offer to D, mover A must first specify which partnership, B or C, he would like to sever in case D accepts the offer. This decision must be made before knowing whether D accepts the offer, and it is implemented automatically if the offer is accepted.

[15] This means that, within a turn, a mover can only make a maximum of 5 offers (fewer if he already already has links). But nothing prevents a mover to re-propose the same match when it is his next turn to play. Also, a match 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 matches, player A makes an offer to B; the offer is rejected; A makes an offer to C; the offer is accepted (A now holds one partner); A makes an offer to D; the offer is accepted (A now holds two partners); A makes an offer to E and commits to drop C if accepted; the offer is accepted (the match with C is dropped and the match with E is added); A makes an offer to F and commits to drop 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 his turn ends for this round.

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 an offer. If the respondent holds less than two partners, he can either accept or reject the offer directly. If the respondent already has two partners, he has to specify which of these two links will be severed just before accepting an offer.[16] If the respondent decides not to drop one of his two partners, 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. Since each player can only make 5 offers in total during his turn, and each offered player has 15 seconds to respond, the duration of a player's turn has a time limit.[17]

All offers made and received remain private information between the two players involved until an offer is accepted and a new link is formed.[18] A description of the computer interface is given in Appendix A, including detailed examples of the game environment and players' actions.

2.3 Payoffs

A key feature of our experiment is that payoffs are pair-specific, that is, fully heterogeneous across players and matches. To illustrate, let i's payoff from matching with j be denoted π_{ij}.We do not require that $\pi_{ij} = \pi_{ji}$, that is, we do not impose that two players benefit equally from the match. In other words, j may be the most desirable

[16] For example, suppose that mover A proposes to D who already holds two partners, say E and F. Respondent D wishes to accept A's offer. To do so, D must first specify which partner, E or F, he drops when accepting A's offer. This guarantees that D never holds more than two matches.

[17] The absolute maximum is to make 5 offers and to sever one or more links, which could last up to 3 minutes: 5×15 seconds for each offer $+5 \times 15$ seconds for each respondent $+2 \times 15$ seconds for each link cancellation = 180 seconds. In practice, a player's turn lasts much less than this because players make fewer than 5 offers each turn and take less than 15 seconds to make or respond to an offer.

[18] To illustrate, imagine that player A has two partners (B and C) and player D also has two partners (E and F): if during his movement A makes an offer to D by conditionally dropping 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 appearing on the screen.

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 matching with j equally: j may be the most desirable partner for i but the least desirable partner for k.[19] The lack of correlation between π_{ij} and π_{kj} means that my payoffs are not informative about others' payoffs: if information about other players' payoff is not provided in the experiment, players cannot infer anything from their own payoffs. To eliminate ties, we impose that each player has a strict ranking over all other players ($\pi_{ki} \neq \pi_{kj}$ for any k, i and j). Operationally, this is achieved by setting a payoff vector of the form $[10, 30, 20, 50, 40]$ for all players, and to set the order of the five values independently for each player.

Because randomization is player-specific, it can happen that one player is 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 partners, this means that not everyone will be able to match with 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 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 gain of each player at the end of a game is the sum of the payoffs from the matches he holds when the game stops.[20] Remaining unmatched generates a payoff of zero. At the end of the experiment, we randomly draw one of the four games played by the group in the session, and players receive the monetary equivalent of their gain for that game.[21] This ensures that participants have a material incentive to form the most profitable matches in each of the four games they play.

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

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

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

2.4 Stable matches and convergence

As mentioned in the introduction, the existence and number of stable matching profiles is uniquely determined by the payoff matrix. To identify and count these stable matching profiles, for each payoff matrix we solve the matching game numerically, by enumeration. This involves looping through all possible network configurations to verify whether they are stable or not. This stable matching profile is then known to the researcher, but unknown to the players – who, even with full information about the payoff matrix, would need a superhuman algorithmic brain to identify a stable match.

We investigate the convergence properties of the game along two key dimensions. First, we conduct a simulation analysis investigating the distribution of stable configurations across randomly selected payoff matrices.[22] As is the norm in matching games, a stable match is defined in terms of two-player deviations – *i.e.*, can two players improve their payoff by dropping one of their existing links and linking to each other instead.[23] We find that only 8% of games do not admit a stable match. Of the remaining games, the large majority (73%) admit a single stable configuration. Only 18% of games admit two stable configurations, and almost none (0.4%) admit three. No game had more than three. For the experiment, we only retain payoff matrices that admit one or two stable configurations. These simulation results should reassure the reader that our analysis is not confined to unusual cases.

Secondly, we simulate how each game would unfold if players followed myopic rational play, defined a weakly dominant strategy where they make all possible dominating offers and accept all dominating offers. All the rules are the same as in the lab experiment, except that agents are replaced with a simple payoff-maximizing heuristic: when it is their turn to play, simulated agents make linking offers to all profitable potential partners, starting with the link that gives them the highest payoff. If an offer is accepted, they drop the least desirable link that they are currently holding. When responding to an offer, simulated agents always drop their least profitable link to accept a payoff-increasing link. We apply this algorithm to all the payoff matrices used in the

[22]The results are based on 500 randomly drawn payoff matrices.

[23]In the context of network formation, this has been called ‘strong pairwise stability’ by Belleflamme and Bloch (2004).

experiment. Results show that convergence to a stable match is achieved in all cases, within 5.4 rounds on average. Since the above simulation essentially implements a Gale-Shapley algorithm adapted to our setting, this result reconfirms that convergence to a stable match is guaranteed, provided that such a match exists – something we ensure by selecting the right payoff matrices.

3 The main treatments

Our experimental protocol naturally produces multiple sources of experimental variation in the base game – such as the variation in payoff vectors across players and the variation in the order of turns within rounds. We also introduce four main treatments described below. Two additional modifications to the main protocol are discussed in Section 5.

3.1 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 partners are most beneficial to themselves. We introduce a full-information treatment (called $T1$) in which players can observe the payoffs of all other players. Operationally, this is achieved by introducing an additional functionality to the screen: in a full information game, i can observe the payoff vector of any other player j by hovering the mouse over j's icon.[24] Figure A2 shows a snapshot of the screen that players see during a game with full information when hovering their mouse over another player's icon. We see the screen of player F at a particular moment of the game when it is F's turn to play: he holds no matches and he is currently browsing the payoffs vector of 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

[24]Even in the full information treatment, players may decide not to check other players' payoffs. A proper understanding of this functionality is carefully tested during the training session. We also record how much time players spend browsing the payoffs of others, which is used in the regression analysis.

but remains intuitive and visual, so as to keep the cognitive burden of the game as low as possible. In games where players can only observe their own payoffs, this hovering feature is switched off (Figures A7-A9).

In the context of our game, the role of information is *a priori* unclear. On the one hand, by accessing this information, a player may gain an idea of the likelihood that an offer would be accepted. As a result, players may refrain from making offers they think will be rejected – perhaps because rejection entails a psychological cost (*e.g.*, Hitsch Hortacsu and Ariely 2010, Belot and Francesconi 2013). Self-censoring of this kind may speed up convergence: less time is spent making doomed offers.

On the other hand, even with full information, players cannot compute the stable configuration by themselves – the game is too complex for that. It is therefore hard to imagine why information should be crucial for players to attain stability: the game is complex but, as illustrated by the simulations discussed above, players do not need information or complex strategies in order to converge to the stable match – myopic rationality will suffice. Given this, observing others' payoffs may prove to be a distraction: players may react to this information overload by adopting complex but incompatible strategies in a setting where strategic behavior is not necessary, and where computing the equilibrium is not an amenable mental calculation.

3.2 Initial configuration

In the base game, the initial configuration is empty – *i.e.*, players start the game with no link. Our second treatment introduces games in which all players start with 2 randomly-assigned partners. We call this $T2$ in the regression analysis of Section 4.

When players start with no link, 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 partners, the player can obtain a positive payoff 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 assigned partners (*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 matched 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 is present among our experimental subjects, we expect a lower rate of convergence to a stable configuration under $T2$.

3.3 Unbalanced vs. multiple stable matches

Some of the experimental variation across games stems from differences in payoff matrices. One dimension that we have already discussed is whether the payoff matrix supports one or two stable matches. In the case of a single stable match, a second dimension of variation is whether in this stable configuration each player has two links – in which case we call the game 'balanced' – or whether some players have fewer than two links – in which case we call the game 'unbalanced'.

In a balanced game, all players have 2 partners each, and there are 12 links overall.[25] All control games are balanced. In the third treatment (called $T3$) we introduce matrices for which the stable configuration is 'unbalanced' in the sense that it contains 10 links only.[26] In unbalanced games, the number of partners and thus payoffs are more unequally distributed. Hence, if matching is affected by other-regarding preferences such as fairness (*e.g.*, Fehr and Schmidt 1999, Blanchflower and Oswaldt 2004), *ceteris paribus* we expect a lower likelihood of convergence to the stable configuration in an unbalanced game.

We define control games as having a single stable configuration. We define games with two stable matches as forming a fourth treatment (called $T4$).[27] When a game has a single stable match, the order of turns (which is randomly assigned) should not matter

[25] There are only two feasible configurations in this case: either all six players form a circle; or they form two circles of three players each.

[26] There are two possible configurations here: either two players are matched to each other and the others form a circle of four players; or one player is isolated and the other five players form a circle.

[27] Only balanced games admit two stable matches.

for convergence. When a game admits two stable configurations, the order of turns can plays a role in selecting one of the two configurations. With two stable configurations, it may be more difficult to converge – for instance because of coordination failure, as players attempt to steer the game towards different configurations. We therefore conjecture that in treatment $T4$, attaining stability may be less frequent and may take more time.

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 the first two treatments: A stands for empty initial configuration and own-payoff information only; B stands for empty initial configuration and full payoff information; C stands for full initial configuration and own payoff information only; and D stands for full initial configuration 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.[28] 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 stable match is unbalanced, *i.e.*, has only 10 matches. Table 1 shows that balanced and unbalanced matches are distributed evenly across groups and letters. Finally, letters in green indicate the balanced games that admit two stable configurations.

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 configuration and own payoff information only. These games share common features – each player starts the game with two randomly assigned partners, and the stable match contains 10 links. But they differ in many other respects: a different payoff matrix (and thus a different unbalanced stable con-

[28]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.

figuration); a different initial configuration; and a different order of turns. This implies that when groups 1 and 2 play game $\underline{C}$, they play two different matching games. We have done so in order to disentangle the effect of the treatments from specific structural properties of the stable configurations that we generate.

3.5 Implementation

Experimental sessions took place in the Parisian Experimental Economics Laboratory between January 2013 and June 2015. The software was coded specifically for this experiment in HTML, Javascript, and Regate.[29] Participants are students enrolled at the University Paris 1 Panthéon-Sorbonne at the time, without distinction of field or discipline. In total we have 48 groups of exactly 6 players each.[30] Half of these players (24 groups) played the main experimental protocol that is the focus of our attention in Sections 2 to 4. The other half of players (24 groups) played two modifications of the main protocol that we discuss in Section 5. The average payment at the end of the experiment was 20.8 euros for about 1.5 to 2 hours of presence in the laboratory.

4 Main results

We start the empirical analysis by examining whether players in the lab are able to converge to a stable match. We then turn to the analysis of the different treatments on outcomes, at three different levels: game, match, and move. 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). The results from additional sessions testing ancillary hypotheses are discussed in Section 5.

[29] Regate is an internet-based software for experimental economics (https://www-perso.gate.cnrs.fr/zeiliger/regate/regate.htm).

[30] We had 14 experimental 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).

4.1 Convergence patterns

Theoretical stability appears to be a surprisingly strong predictor of experimental outcomes: in 83 of 96 games (86%) players converge to a stable match. Overall, more than 96% of links created belong to a stable match. This is because in the 13 games where a stable match is not reached, 70% of the links nonetheless belong to a stable match.[31] Also, when the stable configuration is not achieved, the aggregate payoff is close to the aggregate payoff of the stable configuration (399 *versus* 413 experimental points on average). This is in line with previous findings by Echenique and Yariv (2013) in the context of two-sided matching games. We also find that convergence is relatively fast, and comparable to the simulated speed of convergence assuming myopic rationality.

Could these results have been generated by chance? To investigate this possibility we generate, for each game, 100 random configurations with two links per player. In this way we approximate the profile distribution under the null hypothesis of random matching. We find that, on average, only 37% of randomly generated links happen to belong to a stable match – compared to 96% of links formed during our lab experiment. Since 99.3% of the random matching configurations have 80% or fewer stable links, we firmly reject the null hypothesis that our results are due to chance.

Table 2 reports mean outcomes at game level according to treatment. To recall: $T_1 = 1$ when the game is played under full information about the payoff matrix; $T_2 = 1$ if the initial configuration is non-empty (*i.e.,* the game starts with two randomly assigned partners per player); $T_3 = 1$ if the stable configuration is unbalanced (*i.e.,* has 10 links instead of 12); and $T_4 = 1$ if the game admits two stable matches. The outcomes of interest are as follows. Column (1) shows the proportion of games that converged to a stable match. Column (2) shows the share of final links that belong to a stable match, as a proportion of the links that are realized when the game stops. Column (3) shows the total number of links formed. Column (4) report the total gain obtained at the end of the game by all six players combined, while column (5) reports the total gain in

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

the stable match for comparison purposes.[32] Column (6) reports the total number of rounds played, column (7) the number of accepted offers, and column (8) the number of rejected offers.

As Table 2 show, several outcomes of interest are consistent across treatments - this seems to be the case for columns (1) to (5).[33] On the other hand, the number of rounds (which is a proxy of the speed of convergence) and the number of offers accepted and rejected display more variability across treatments. This variability is the object of regression analysis in the next Section. A comparison between columns (4) and (5) further suggests that total realized gains are close to the total gains in the stable match. Some total realized gains are even higher than in the stable match – to recall, in our game, a stable match is not necessarily efficient.

4.2 The role of information

Next we turn to variation in game outcomes due to treatments. We start by reporting an analysis of results from the 96 games presented in Table 1. Table 3 reports the results of linear regressions of the form:

$$y_i = \beta_0 + \beta T_g + \lambda_g + \lambda_{gr} + \varepsilon_i \tag{1}$$

where y_i represents one of the experimental outcomes presented in Table 2, column (1)-(4) and (6)-(8). The vector T_g represents the four game-level treatment dummies (T_1 to T_4). We include game order effects λ_g (*i.e.* a set of dummies for the order in which the game was played from 1 to 4) to control for possible learning, and group fixed effects λ_{gr} to allow for possible common shocks.[34] Standard errors are clustered at the group level, which is the highest level at which participants interact in the experiment.

In line with the descriptive statistics shown in Table 2, the regression results presented in columns (1) and (2) indicate that players consistently converge to the stable

[32]Where there are two stable matches, we report the average.

[33]Except for treatment T_3 which mechanically reduces the number of links formed and, consequently, gains in the lab.

[34]Since players and groups are nested into sessions, we cannot include session fixed effects as they are collinear with group fixed effects.

match in all four treatments. The full information treatment T_1 does not affect convergence to a stable match. But it increases the total number of formed links as well as the total realized gains (the effects are significant at 10% level). It also reduces the time needed to converge and the number of rejected offers.

The increase in total gains under full information arise due to three combined effects. First, as shown in column (3) of Table 3, players form more links under full information, and this tends to mechanically increase payoffs. Secondly, when players do not reach the stable configuration, they still achieve a higher aggregate payoff under full information: in the no information treatment, the aggregate payoff is lower than in the stable match for 5 out of the 6 games where this stable match is not reached; in the full information treatment, this is observed in only 2 cases out of the 7 games where the stable match is not reached. Thirdly, when the game has two Pareto-ranked stable configurations, under full information the high configuration is selected more often: in all such games with incomplete information, play converges to the low match, while in all such games with full information it converges to the high match. The reader should nonetheless keep in mind that the number of games with Pareto-ranked matches is probably too small to regard these results as definitive.[35]

The reduction in the number of rounds played with full information is largely a consequence of the reduction in the number of rejected offers. In contrast, full information has no effect on the number of accepted offers. What this suggests is that, 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 (2013), but in the context of a laboratory experiment. In Section 2 we argued that excessive self-censoring may prevent players from reaching the stable configuration. The laboratory evidence suggests that, under our experimental conditions, these fears are unfounded.

The remaining results offer no surprises. The unbalanced treatment reduce the number of realized links and the total gains, but these are a mechanical consequences

[35] We also note that, when two Pareto-ranked matches are available (9 games out of 96), the aggregate difference in gains is on average small (14.4 points). Yet, due to randomization, it happens to be slightly higher for the 5 games with full information (18 points) than in the 4 games with incomplete information (10 points).

of the fact that the unbalanced configurations have fewer links. Other treatments have no effect on any of the aggregate outcomes. In summary, contrary to some expectations, attaining a stable match is equally likely under all treatments, albeit a bit slower without full information.

4.3 Inertia and fairness

We now investigate the determinants of matching from the players' perspective. 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 of Table 1. We estimate linear regressions of the form:

$$y_{ijg} = \beta_0 + \beta_1 A_{ijg} + \beta_2 X_{ijg} + \beta_3\, EQ_{ijg} + \beta T_g + \lambda_g + \lambda_{ij} + \varepsilon_{ijg} \tag{2}$$

where the dummy y_{ijg} equals one if dyad ij is linked when game g ends. Variables A_{ijg}, X_{ijg} and EQ_{ijg} denote three experimentally assigned, dyad- and game-specific dummy variables of interest: A_{ijg} takes value 1 if link ij appears in the initial configuration of treatment T_2. X_{ijg} takes value one when the absolute difference between π_{ij} and π_{ji} is large, *e.g.*, exceeds 20 points, in the full-information treatment T_1.[36] EQ_{ijg} takes value one if match ij belongs to the stable configuration.[37] If players are reluctant to sever initial 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 stable configuration or not. If subjects display other-regarding preferences, such as a taste for fair outcomes, they may refrain from links that yield very unequal payoffs to the two players involved. In this case, we expect $\beta_2 < 0$: the more unequal the distribution of payoffs is, the lower is the likelihood that the link was formed. Treatment dummies T_g includes the four game-level treatments as before. We also include game order effects λ_g and dyad fixed effects λ_{ij} as controls. The former are identified by variation across

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

[37] When there game admits two stable matches, we focus on the configuration which was attained or closer to be attained in the game.

dyads in the same game; the latter are identified by systematic variation across games for the same dyad. We cluster errors are the group level, which takes care of any arbitrary patterns of intra-group correlation in errors.[38]

Regression results are reported in Table 4. We find that β_1 is not statistically different from 0: being matched with a partner at the beginning of the game has no effect on the realized match configuration. This suggest that inertia does not play a role in our game, and partnerships are easy to sever. Coefficient β_2 is also not significant – this suggests that fairness does not seem to affect matching in our experiment.[39] As expected, the coefficient of EQ_{ijg} seem to explain most of observed links. The other results are in line with previous findings, and the coefficient of T_4, which was already negative in the column (3) of Table 3, now becomes marginally significant.

4.4 Players' actions

4.4.1 Irrational matching choices

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 Ho and Chong 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).

We wish to ascertain the extent to which similar difficulties arise in our game. Assessing the overall extent to which players' actions are 'rational' 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

[38]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 connected with j is not independent from the likelihood that i is connected with k.

[39]The results from an experiment by Belot and Fafchamps (2016) 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.

assumptions that players make about other players' strategies are reasonable. What we can do, however, is to document under which conditions players' actions deviate from what we call myopic best response – not undertaking an action that decreases one's own total payoff at that moment of the game.

We identify four types of actions that strictly violate myopic best response, two for movers and two for respondents. For movers these violations are: (1) dropping a link without forming another; (2) making a dominated offer.[40] For respondents these violations are: (3) refusing a dominating offer; and (4) accepting a dominated offer. We name these actions 'irrational matching choices'. The incidence of irrational matching choices by treatment is reported in Table 5. One could argue that failing to making dominating offers is also irrational. But it is only weakly so: if the player thinks the offer will be rejected, making it would not increase his payoff – and thus is not strictly better. To avoid these complications, we use only the four types of actions listed above in the empirical analysis.

Note that, in our experiment, irrational matching choices do not *per se* prevent convergence to a stable match: dominated offers may be refused, and players can undo irrational actions later in the game. It is however possible that players make no irrational matching choices as defined above, but still do not reach a stable match. This would arise if players consistently refrain from making offers that belong in the stable match. Indeed, in our game convergence needs two ingredients: that players don't stick to the same irrational choices over and over again, and that they are willing to make enough offers to potential partners. Proving this formally is beyond the scope of this paper, but we feel reassured by the fact that the large majority of our lab games has converged to a stable configuration. Therefore, in what follows we document under which conditions players deviate from the minimal rationality criteria defined above.

[40]Formally, let ij denote the link currently being proposed and let s_i denote the payoff that mover i is offering to drop in order to form a new link. If i currently has less than two partners, then $s_i = 0$. If i currently has two partners worth π_{ik} and π_{im} and offers to sever ik if the new link is formed, then $s_i = \pi_{ik}$. 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 $\pi_{ij} < s_i$.

4.4.2 Movers

We first direct our attention to the actions taken by movers. 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 active actions, such as making offers or deleting links. Over the 96 games, we observe 3205 mover actions from 1980 unique turns. 865 actions (27%) consist in keeping the *status quo* and passing the turn, while 2340 actions (73%) are active actions. We find that the large majority of active actions (97%) do not violate rules (1) and (2) above. This is, by itself, a remarkable finding. Only 70 active actions (3%) strictly violate myopic best response: in 35 instances the mover drops a link without forming another one; and in another 35 instances the mover makes an offer which is payoff-dominated by the link he conditionally deletes.

In order to investigate whether certain experimental conditions make movers more prone to make irrational matching choices, we start by estimating a linear regression of the form:

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

where y_{ir} is the share of irrational choices in the 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 that mover i spends browsing the history of the current game during round r; $time\,payoffs_{ir}$ which represents the number of seconds that mover i spends browsing the payoffs of other players during round r;[41] and the dummy $already\,2\,partners_{ir}$ 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 captures the effect of time within a game), game order effects λ_g, and player fixed effects λ_i.

Results are shown in column (1) of Table 6, taking as unit of observation all unique turns ($n = 1980$). They indicate that when a player spends more time browsing other

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

players' payoffs, he is *more* likely to take actions that, from the point of view of myopic best response, appear irrational. Keep in mind that in our game it is virtually impossible for someone to work out the stable configuration through mental calculation – there simply are too many combinations to consider. We therefore conjecture that when players spend much time examining the payoffs of others, they end up making irrational matching choices because they either over-think the game, *e.g.*, try to solve for the stable match and/or 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 to refrain from such actions: the coefficient of the second, third and forth games are all significantly negative and they increase in magnitude. We also observe that the coefficient of $already\,2\,matches_{ir}$ is significantly positive – but this is a consequence of the fact that deviations of type (2) can only occur when the mover already has two partners. Time spent on history has no impact, and the same holds for the four main treatments. This is in line with our earlier finding (Table 3) that most games reach a stable match irrespective of treatments.

In columns (2) to (4) we continue the analysis of movers' behavior by focusing not on decisions that actively violate myopic rationality as in column (1), but rather on situations where the subject fails to undertake a potentially beneficial action. We interpret such situations are indicative of satisficing behavior. We first examine those cases where, at the beginning of his turn, a mover is not currently holding his two most desirable partners (*i.e.*, those links worth 40 and 50). There are 1379 turns for which this is true. In such a configuration, a player may continue making offers in the hope of securing his two most desirable payoffs. But making the same offers repeatedly may see them rejected multiple times.[42] If players derive a subjective dis-utility from repeated rejections, they may refrain from making such offers. This analysis is reported in the second column of Table 6, where we re-define the dependent variable of Equation (3): now y_{ir} takes value 1 if the mover passed his turn without taking any action, and 0

[42]In our data only a minority of proposals are repeated (56% of proposals are made only once within the same game, and only 8% of proposals are made more than three times). These repeated proposals tend to come early in the game (61% of them are made within the first three rounds, and 75% within the first four rounds). The (unconditional) probability of being accepted is 52% for a first-time proposal, and then drops to a stable 20% afterwards.

otherwise. We observe a strong round effect: players who did not yet attain their two most desirable links are more likely to make no offers as the game progresses. This is consistent with rejection avoidance – or more generally with not wanting to waste time in a satisficing perspective: once players have secured some partners, the need to make offers is less pressing. We do indeed find that players who already have two partners 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 that information leads to self-censoring.

We continue this investigation in column (3) where y_{ir} represents the number of 'wish-list' offers made during the turn – *i.e.*, the number of offers made that would increase the mover's payoff if they were accepted. In column (4) we refine this variable to only include offers to the most desirable potential partner at the beginning of round r.[43] Results confirm earlier findings. Movers are less likely to make wish-list offers when they already have two partners, 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 treatment marginally increases the number of wish-list offers in column (3) – possibly because players with zero or one partner 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).

We now take a different perspective on movers' actions to investigate the impact of the history of play. We take as unit of observation all the potential offers that could have been made in each round, and create a dependent variable y_{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 the match ij was already in existence.[44] We

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

[44] This is easily illustrated with an example. In round 1 player A has no partner. 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 is matched to C and D. In this round A can make three offers: AB, AE, AF and thus we have three dyadic observations.

further subdivide the observations into two groups: those for which making an offer would increase i's payoff;[45] and those for which making an offer would decrease it. The first group corresponds to dominating offers, which do not violate rationality; and the second group corresponds to dominated offers, which violate myopic best response.

We estimate a linear regression model of the following form on each of these two sets of observations separately:

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

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.[46] The first regressor 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, which can be due to better-informed choices and/or to the subjective cost of anticipated 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 an attempt to re-match after a previous severance (or refusal) does not necessarily signal inconsistency in player behavior. It may naturally arise as a result of the sequential process through which the game is organized. As players cycle through offers, it is quite possible for j to drop a link to i to form a more advantageous link with k, only to see this better link dropped by k later – at which point j may be willing to re-link with i.[47] We also control for π_{ijg} directly – the larger the payoff, the more likely an offer may be. As before, we include dummies for the four treatments, as well as round number, game order, and player fixed effect. As in earlier regressions, standard errors are clustered at

[45] If the mover has less than two partners at the beginning of round r, all potential offers are payoff-increasing.

[46] 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.

[47] 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 partners. 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 way the game unfolds.

the group level.

Regressions results are presented in Table 7. They indicate that, on average, personal history of play during the game does not affect decisions to make an offer. This is reassuring because taking offense for past rejection may prevent convergence to a stable configuration. However, if we interact previous refusal with the full-information dummy (results available upon request), we find that subjects in the full-information treatment are less likely to re-make a previously refused offer. The effect is significant at the 10% level, and only for payoff-increasing offers. A likely explanation is that, when subjects are informed about the payoff vector of other players, they can see when the other player derives little benefit from linking with them and thus when there is little point in renewing their offer.

4.4.3 Respondents

Next we turn to respondents, that is, players who have received an offer and must decide to accept it or not. We observe 2305 responses. Of these, 2117 (92%) do not violate myopic best response: the respondent accepts a dominating offer and rejects a dominated offer. 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 partners – and thus should accept any offer – and 61 when he already has two partners. 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 the determinants of this behavior, we take as unit of analysis all 2305 responses and estimate a linear regression model of the form:

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

where a_{jir} equals 1 if player j violated myopic best response by rejecting a dominating offer or by 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 are as before.

Coefficient estimates for equation (5) with no X_{jir} regressors are reported in the first column of Table 8 for comparison. We observe that, as anticipated, a respondent is less likely to reject an offer with a high payoff π_{jig}. The full information treatment is associated with a higher tendency to reject a dominating offer (or to 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. We find that when these regressors are included, the full information treatment dummy is no longer significant. This suggests that spending much time consulting the payoff vector of other players is associated with departures from myopic best response for respondents as well. This is in line with our earlier finding for movers: deviation from myopic best response seems to occur when players are trying to come up with a more complex strategy – something that, in this game, is very difficult to do (and is not necessary to reach a stable match). This suggests that providing full information on others' payoffs can be a temporary distraction for players.

In columns (3) and (4) of Table 8, 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 observing irrational matching choices. As noted above, refusing a dominating offer is one important source of departure from myopic best response in our experiment. What columns (3) and (4) suggest is that this behavior is partly due to a refusal to reconnect with players who have 'mis-behaved' in the past, *i.e.*, who have rejected a previous offer or who have dropped a pre-existing partnership.[48] This claim is also supported by additional evidence at the link level: if we analyze the history of all dyads before the end of each game, we see that at some point a proposal was made and refused for 51% of them, and a link was formed and severed for 31% of them. However, if we restrict our attention to links that belong to a stable match but are not formed in the lab, these percentages rise to 80% and 52% respectively.

[48] If we interact previous refusal or previous severance with the information treatment dummy, we find that the effect is stronger in the information treatment, but the difference is not statistically significant.

This suggest that in most cases the stable configuration is not reached not because the equilibrium links were never attempted, but because they were severed or refused earlier in the game, and the victims of a rejection have refused subsequent offers to 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 match for fear of not being able to get it back later on, should a more promising partner prove to be unreliable. What is remarkable is that, in our experiment, these fears are not strong enough to bring the decentralized matching process to a halt and prevent convergence to the stable configuration most of the time. But we nonetheless find some evidence that players do take offense for rejection and broken partnerships and this does impinge on convergence.

5 Other treatments

As mentioned earlier, we also implemented two other modifications of the main experimental protocol. The purpose of these modifications is to test two ancillary hypothesis, which we describe now.

5.1 Negative payoffs

In the main experimental protocol, the value of holding no partner is normalized to zero, which means that any link is better than no link. In the language of network theory, this means that any network configuration with two links per player is pairwise stable: no player would unilaterally sever a link. We relax this feature by inviting 12 additional groups of players from the same population to play matching games where the payoff matrices admit only one pairwise stable match – that is, only one match configuration is robust to deviations of both size-one and size-two coalitions. In this treatment, we take a payoff matrix from Section 2.3 and we modify it such that all the links that do not belong to the stable match yield a negative payoff for at least one of the players involved.[49] This transformation ensures that no configuration other than the stable match is pairwise stable, *i.e.*, robust to unilateral deviations. The rest of the experimental protocol is kept unchanged. The sequencing of information and initial configuration treatments is the same as in Table 1, Block 1.

We find that 100% of the games with negative payoffs converge to their unique stable configuration, and they do so faster than in the main sessions (it takes one round less to converge on average). This is consistent with the idea of satisficing behavior in the main treatment: players try less hard when there is less to lose. Furthermore, when we look for evidence of irrational matching choices in the path to stability, we find that much fewer actions deviate from myopic best response (*e.g.*, less than 3% for respondents, compared with 8% in the main sessions).

5.2 Partial information

We also further investigate the role of information. To do so, we invited 12 groups of players to play what we call a partial information treatment. In this treatment, each player i sees not only his payoff π_{ij} from matching with j, but also j's payoff π_{ji} from matching with him. But i 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 matching with other players (π_{jk} and π_{kj} for all other j, k). This information treatment lies in between the control game (where the player sees only his own payoff) and the full information game (where the player has access to the entire payoff matrix). In this treatment the possibility of self-censoring is present, but the scope for elaborating complex (and unsuccessful) strategies is more limited. Here too we use the treatment sequencing from Block 1 in Table 1, except that partial information replaces full information – *i.e.*, with letters B and D now refer to the partial information treatment. The rest of the experimental protocol is essentially the same.[50] We find that the proportion of games converging to a stable match is virtually identical to the main sessions. In Table 9 we replicate the game-level analysis

[49]For example, if the ij match is not stable, then we set either $\pi_{ij} = -10$ or $\pi_{ji} = -10$.

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

of Table 1 adding the games from the partial information sessions.[51] The results are very similar to those reported in Table 3: the full information treatment has an effect on the number of links formed, the total 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

Many departures from rationality and self-interest have been studied in the lab, but few experiments have focused on decentralized matching and none has introduced competition for partners. Our paper fills this gap and provides new insights on the design of decentralized matching games of deferred acceptance and on the determinants of players' behavior in such games.

We design a laboratory experiment to investigate behavior in a matching game with deferred acceptance in which players have heterogeneous preferences. Organized in the manner of a board game, the experimental protocol is decentralized and interactive: when their turn comes, players are free to make offers and counter-offers to multiple partners. But they do so in a sequential manner and deferred acceptance is externally enforced. We select payoff matrices for which this game has either one or two stable match configurations – where stability is defined in terms of two-player deviations. We study whether players are able to reach a stable match with no centralized guidance, and which individual motivations are associated with irrational matching choices.

We observe a surprisingly high rate of convergence to a stable match, in spite of the complexity of the game. One possible interpretation is that competing for the best partner is a scenario for which subjects have good heuristics, probably because these situations are ubiquitous in real life. We find little or no evidence that play is affected by inertia or other-regarding preferences (altruistic or invidious), but some observed behavior is consistent with a satisficing heuristic. Importantly we find that lack of information on others' payoffs does not prevent convergence to a stable match: with

[51] We have 47 (instead of 48) of such games – because of a problem in the parametrization in the laboratory, one game needed to be excluded from the analysis.

our experimental design, subjects do not need that information to reach stability as long as they experiment enough with offers and counter-offers. More information does, however, speed up convergence thanks to self-censoring. We trace irrational matching choices mostly to two sources: the tendency of over-think in a setting where strategic thinking is not necessary; 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.

This last finding is particularly striking because it suggests the existence of a behavioral tendency to punish disloyalty in matching markets. This tendency is inimical to deferred acceptance as it can lead to unraveling. To illustrate, imagine a population of agents who compete in decentralized matching games with deferred acceptance. Suppose that by playing these games repeatedly against each, some players build a reputation for refusing offers from those who have been disloyal. This means that these players are making one-off, take-it-or-leave-it offers. It is easy to see that such reputation puts them at an advantage: other players will think twice before dropping one of their offers – *i.e.*, they will be loyal. Since dropping an offer is only useful upon receiving a better offer, loyalty leads to unraveling and turns a game of deferred acceptance into a sequential matching market. In our experiment, players could not build a reputation since we reshuffled their identity across games and each game was short. In spite of this, some players showed an instinctive willingness to punish those who betrayed them.

These findings have implications for many real-life problems in organization and personnel economics that pertain to the formation of teams. Centralized matching algorithms were developed at a time when rapid internet-based interaction was impractical. Things have changed: many *P2P* decentralized matching markets now operate through interactive apps. At this point in time, however, they tend to operate sequentially: a match is final once it is accepted. In contrast, online auctions implement deferred acceptance but focus on a single good or match at a time. We believe that there may be situations in which *P2P* decentralized matching with deferred acceptance can achieve better outcomes than either of these two options. Examples include moderate-size matching markets that are currently run through a clearing house – *e.g.*, assignment of students to dorms or classes, centralized job markets, assignment of pupils to schools. For instance, the specific design used for this paper could easily be adapted for matching individuals in multiple teams of two – *e.g.*, homework team assignments, team-based sports tournaments, and online gaming.

References

[1] Abdulkadiroğlu, A., P.A. Pathak, A.E. Roth, and T. Sönmez, (2005): "The Boston public school match", *American Economic Review Papers & Proceedings*, vol. 95(2), pp. 368–71.

[2] Agranov, M., and M. Elliott: (2016) "Commitment and (In) Efficiency: A Bargaining Experiment." mimeo.

[3] Belleflamme, P. and F. Bloch (2004): "Market Sharing Agreements and Collusive Networks", *International Economic Review*, 45: 387-411.

[4] Belot, M. and M. Fafchamps (2016): "Are People Equally Other-Regarding When Picking a Partner vs Choosing an Allocation?", mimeo.

[5] Belot, M. and M. Francesconi (2013): "Meeting Opportunities and Mate Selection: A field study", *Journal of Human Resources*, 48(2), 474-508.

[6] Blanchflower, D. and A. Oswald (2004): "Well-Being over Time in Britain and the USA", *Journal of Public Economics*, 88 (7-8).

[7] Burger, M. and V. Buskens (2009): "Social context and network formation: An experimental study", *Social Networks*, 31: 63-75.

[8] Camerer, C. , T. Ho and J. Chong (2004): "A Cognitive Hierarchy Model of Games", *Quarterly Journal of Economics*, 119(3): 861-98.

[9] Caria, S. and M. Fafchamps (2015): "Can Farmers Create Efficient Information Networks? Experimental Evidence from Rural India", CSAE Working Paper WPS/2015-07, Department of Economics, Oxford University.

[10] Carrillo, J. and A. Gaduh (2012): "The Strategic Formation of Networks: Experimental Evidence", CEPR Discussion Paper No. DP8757.

[11] Calsamiglia, C., G. Haeringer, and F. Klijn (2010): "Constrained School Choice: An Experimental Study", *American Economic Review*, 100(4): 1860-74.

[12] Charness, G., M. Corominas-Bosch, and G. Frechette (2007): "Bargaining and network structure: An experiment," *Journal of Economic Theory* 136.1 : 28-65.

[13] Chen, Y. and T. Sonmez (2006): "School Choice: An Experimental Study", *Journal of Economic Theory*, 127, 202-231.

[14] Conte, G. D. Di Cagno and E. Sciubba (2009): "Strategies in Social Network Formation", Birkbeck Working Paper in Economics and Finance n. 0905.

[15] Costa-Gomez, M.A. and V.P. Crawford (2006): "Cognition and Behavior in Two-Person Guessing Games: An Experimental Study", *American Economic Review*, 96(5): 1737-68.

[16] Crawford, V.P. and N. Iriberri (2007): "Level-k auctions: can a non-equilibrium model of strategic thinking explain the winner's curse and overbidding in private-value auctions?", *Econometrica*, 75(6): 1721-70.

[17] Danziger, S., J. Levav and L. Avnaim-Pesso (2011): "Extraneous Factors in Judicial Decisions", *Proceedings of the National Academy of Sciences*, 108(17): 6889-6892.

[18] Deck, C. and C. Johnson (2004): "Link bidding in laboratory networks", *Review of Economic Design*, 8: 359-372.

[19] Demuynck, T. and J. Vandenbossche, (2013): "Network formation with heterogeneous agents and absolute friction", *Computational Economics*, 42, 23-45.

[20] Di Cagno, D, and E. Sciubba (2008): "Are Individuals Profit Maximising in Network Formation? Some Experimental Evidence", in *Advances in Decision making under risk and uncertainty*, Springer Theory and Decision Library, pp. 219-241.

[21] Echenique, F. and L. Yariv (2013): “An Experimental Study of Decentralized Matching”, mimeo.

[22] Echenique, F. and J. Oviedo (2006): “A theory of Stability in Many-to-many Matching Markets”, *Theoretical Economics*, 1(2), pp 233-273.

[23] Eriksson, K., Strimling, P. (2009): “Partner Search Heuristics in the Lab: Stability of Matchings Under Various Preference Structures”, *Adaptive Behavior* 17: 524-536.

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

[25] Gale, D. and L. Shapley (1962): “College Admissions and the Stability of Marriage”, *American Mathematical Monthly*, 69, 9-15.

[26] Gintis, H., S. Bowles, R. Boyd, and E. Fehr (2006): “*Moral Sentiments and Material Interests : The Foundations of Cooperation in Economic Life*”, MIT Press, Cambridge Mass.

[27] Haeringer, G. and M. Wooders (2011): “Decentralized Job Matching”, *International Journal of Game Theory*, 40, 1-28.

[28] Hitsch, G., A. Hortacsu, and D. Ariely (2010): “Matching and Sorting in Online Dating”, *American Economic Review*, 100(1): 130-163.

[29] Irving, R.W. (1985): “An Efficient Algorithm for the Stable Roommates Problem”, *Journal of Algorithms* 6, 577-595.

[30] Jackson, M. and A. Watts (2002): “The Evolution of Social and Economic Networks”, *Journal of Economic Theory*, 106 (2), 265-295.

[31] Jackson, M. and A. Wolinsky (1996): “A strategic model of social and economic networks”, *Journal of Economic Theory*, 71: 440-74.

[32] Kagel, J.H. and A.E. Roth (2000): "The dynamics of reorganization in matching markets: a laboratory experiment motivated by a natural experiment", *Quarterly Journal of Economics*, 115 (1) 201–235.

[33] Kahneman, D. (2011)*:* "*Thinking Fast and Slow*", Farrar, Straus and Giroux, McMillan, New York.

[34] Kahneman, D., J. Knetsch, and R. Thaler (1991): "Anomalies: The Endowment Effect, Loss Aversion, and Status Quo Bias", *Journal of Economic Perspectives*, 5: 193-206.

[35] Kelso, A. and V. Crawford (1982): "Job Matching, Coalition Formation, and Gross Substitutes", *Econometrica*, 50(6), p. 1483-1504.

[36] Kirchsteiger, G., M. Mantovani, A. Mauleon and V. Vannetelbosch (2016): "Limited Farsightedness in Network Formation", *Journal of Economic Behavior & Organization,* 128, 97-120.

[37] Kosfeld, M. (2004): "Economic Networks in the Laboratory: A Survey", *Review of Network Economics*, vol. 3(1): 19-41.

[38] Koszegi, B. and M. Rabin (2009): "Reference-Dependent Consumption Plans", *American Economic Review*, 99: 909-36.

[39] Kubler, D., M. Dargnies and R. Hakimov (2016): "Self-confidence and Unraveling in Matching Markets", WZB Berlin Social Science Center (mimeograph).

[40] McKinney M.N., M. Niederle, A.E. Roth, (2005): "The collapse of a medical labor clearinghouse (and why such failures are rare)", *American Economic Review*, 95(3), pp. 878-889.

[41] Nalbantian, H. R. and A. Schotter (1995): "Matching and Efficiency in the Baseball Free-Agent System: An Experimental Examination", *Journal of Labor Economics*, 13(1), 1-31.

[42] Nelson, R. and S. Winter (1982): "*An Evolutionary Theory of Economic Change*", Harvard UP, Cambridge MA.

[43] Niederle, M. and A.E. Roth (2009): "Market Culture: How Rules Governing Exploding Offers Affect Market Performance", *American Economic Journal: Microeconomics*, 1(2): 199-219.

[44] Niederle, M. and L. Yariv (2011): "Decentralized Matching with Aligned Preferences", mimeo.

[45] Okumura, Y. (2016): "A one-sided many-to-many matching problem", mimeo.

[46] Pais, J., Á. Pintér, and R. Veszteg (2012): "Decentralized Matching Markets: A Laboratory Experiment", Working Paper from Departamento de Economia ISEG, wp08/2012/DE/UECE.

[47] Rabin, M. and R. Thaler (2001): "Anomalies: Risk Aversion", *Journal of Economic Perspectives* 15: 219-32.

[48] Roth, A.E. (1991): "A natural experiment in the organization of entry-level labor markets: regional markets for new physicians and surgeons in the United Kingdom", *American Economic Review* 81, pp. 414-440.

[49] Roth, A.E et E. Peranson (1999): "The Redesign of the Matching Market for American Physicians: Some Engineering Aspects of Economic Design", *The American Economic Review*. 89 (4): 756–757.

[50] Roth, A.E., T. Sönmez and M.U. Ünver (2005a): "Pairwise kidney exchange", *Journal of Economic Theory*, vol. 125(2), pp. 151–88.

[51] Roth, A.E., T. Sönmez and M.U. Ünver (2005b): "A kidney exchange clearinghouse in New England", *American Economic Review, Papers and Proceedings*, vol. 95(2), pp. 376–80.

[52] Roth, A.E. (2016): "Game Theory and Market Design", NBER Summer Institute 2016 Methods Lectures, *http://nber.org/econometrics_ minicourse_ 2016/*

[53] Simon, H. (1956): "Rational choice and the structure of the environment", *Psychological Review*, 63(2), 129-138.

[54] Ünver, M.U. (2005): "On the survival of some two-sided matching mechanisms: an experimental and computational investigation of the stability hypothesis", *International Journal of Game Theory*, 33(2), pp 239-254.

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 equilibria, letters in green indicate games with two equilibria.

Table 2: Mean outcomes at game level, by treatment

	(1) reach equilibrium	(2) % eq. matches formed	(3) n. matches formed	(4) tot. gains in lab
TOT	0.86	0.96	5.53	426.25
T1=0	0.88	0.96	5.50	422.29
T1=1	0.85	0.95	5.56	430.21
T2=0	0.88	0.96	5.54	425.83
T2=1	0.85	0.95	5.52	426.67
T3=0	0.88	0.96	5.92	443.00
T3=1	0.85	0.96	5.11	408.04
T4=0	0.86	0.95	5.48	424.76
T4=1	0.92	0.99	5.92	436.67

	(5) tot. gains in equilibrium	(6) n. rounds	(7) n. offers accepted	(8) n. offers rejected
TOT	427.76	3.44	9.02	14.99
T1=0	427.71	3.83	10.31	18.27
T1=1	427.81	3.04	7.73	11.71
T2=0	426.15	3.31	10.17	14.35
T2=1	429.38	3.56	7.88	15.63
T3=0	448.50	3.58	10.12	13.90
T3=1	405.22	3.28	7.83	16.17
T4=0	426.07	3.42	8.70	14.90
T4=1	439.58	3.58	11.25	15.58

Table 3: Analysis of games

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	reach equilibrium	% eq. matches formed	n. matches formed	tot. gains in lab	n. rounds	n. offers accepted	n. offers rejected
T1 (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)
T2 (2 initial matches)	-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)
T3 (unbalanced eq.)	-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 eq.)	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
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 4: Match-level Analysis

VARIABLES	match
A_{ijg} (initial match)	0.017
	(0.018)
X_{ijg} (extreme match)	0.042
	(0.026)
EQ_{ijg} (equilibrium link)	0.934***
	(0.025)
T1 (full information)	-0.000
	(0.006)
T1 (2 initial matches)	-0.008
	(0.010)
T3 (unbalanced eq.)	0.003
	(0.003)
T4 (double eq.)	-0.014*
	(0.008)
game n. 2	0.009
	(0.007)
game n. 3	0.005
	(0.005)
game n. 4	-0.000
	(0.004)
dyad fixed effect	yes
Constant	0.018**
	(0.007)
Observations	1440
R-squared	0.874

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

Table 5: Irrational matching choices by treatment

	proposals		
	tot proposals (N)	drop a match (%)	make a dominated offer (%)
TOT	2340	1.5	1.5
T1=0	1396	1.7	1.4
T1=1	944	1.2	1.6
T2=0	1188	0.9	1.8
T2=1	1152	2.1	1.2
T3=0	1221	1.6	1.5
T3=1	1119	1.3	1.5
T4=0	2016	1.6	1.6
T4=1	324	0.6	0.9
	responses		
	tot responses (N)	accept dominated offer (%)	reject dominating offer (%)
TOT	2305	1.5	7
T1=0	1372	1.5	5.4
T1=1	933	1.3	8.7
T2=0	1177	1.1	7.5
T2=1	1128	1.8	5.9
T3=0	1201	1.3	7.1
T3=1	1104	1.6	6.3
T4=0	1983	1.6	6.5
T4=1	322	0.6	8.1

Table 6: Movers analysis

	(1)	(2)	(3)	(4)
	% violations	status quo	n. wishlist offers	1st wishlist offer
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 partners	0.024***	0.206***	-1.322***	-0.132***
	(0.007)	(0.021)	(0.078)	(0.024)
T1 (full information)	-0.011	0.330***	-1.077***	-0.346***
	(0.007)	(0.033)	(0.096)	(0.032)
T2 (2 initial matches)	-0.002	-0.030	0.026	0.002
	(0.005)	(0.019)	(0.060)	(0.018)
T3 (unbalanced eq.)	0.004	0.011	0.130*	0.014
	(0.006)	(0.018)	(0.063)	(0.026)
T4 (double eq.)	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)
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 7: **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)
payoff	0.012***	0.012***	0.000	0.001
	(0.001)	(0.001)	(0.000)	(0.000)
T1 (full information)	-0.137***	-0.135***	-0.002	-0.002
	(0.021)	(0.021)	(0.005)	(0.005)
T2 (2 initial matches)	0.038*	0.034	-0.003	-0.003
	(0.019)	(0.020)	(0.005)	(0.005)
T3 (unbalanced eq.)	0.067**	0.066**	-0.002	-0.003
	(0.025)	(0.025)	(0.005)	(0.005)
T4 (double eq.)	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)
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 8: Respondents analysis

	(1)	(2)	(3)	(4)
	Violation of myopic best response			
payoff	-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 (full information)	0.019*	-0.021	0.020*	0.020*
	(0.010)	(0.015)	(0.010)	(0.010)
T2 (2 initial matches)	-0.004	-0.002	-0.006	-0.007
	(0.011)	(0.012)	(0.011)	(0.011)
T3 (unbalanced eq.)	-0.012	-0.015	-0.011	-0.010
	(0.010)	(0.010)	(0.010)	(0.010)
T4 (double eq.)	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)
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 9: game-level analysis, partial vs. full information

	(1) reach equilibrium	(2) % eq. matches formed	(3) n. matches formed	(4) tot gains in lab	(5) n. rounds	(6) n. offers accepted	(7) n. offers refused
T1 (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 (2 initial matches)	-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 (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 eq.)	-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 eq.)	-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
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 make an offer 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 matching 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 matches 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 match 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: drop an existing partner, make an offer, 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 has no match) who has made an offer to A and is waiting for a response. In case the mover is already holding two other partners, one of those must be deleted if the new offer is accepted, and this information is also depicted graphically on the screen: the two appear in red and the mover is asked to select the partnership to delete in case the new offer is accepted, which then turns into a red dotted line. Figure A4 represents player B who is matched to C and A, and has made an offer to F – he's ready to drop 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 partnership – Figure A6 represents player D about to confirm the deletion of his match with player E.

Similarly, when a respondent receives an 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 has two partners, he is asked to select one to drop (Figure A8). Upon his choice, the offer will be considered accepted and turns into a continuous black line while the line 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 offers that do not involve him directly. So if player i is making an offer to j, this is only visible to players i and j - the new line 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 matched is intentioned to drop him if his 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

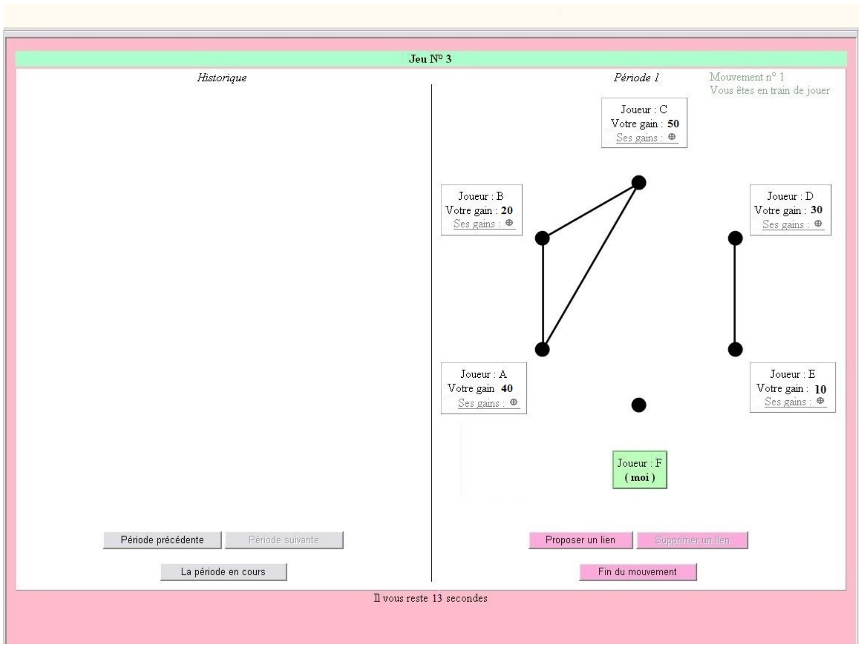

Jeu N° 3
Historique
Période 1
Mouvement n° 1
Vous êtes en train de jouer
Joueur : C
Votre gain : 50
Ses gains :
Joueur : B
Votre gain : 20
Ses gains :
Joueur : D
Votre gain : 30
Ses gains :
Joueur : A
Votre gain 40
Ses gains :
Joueur : E
Votre gain : 10
Ses gains :
Joueur : F
(moi)
Période précédente
Période suivante
La période en cours
Proposer un lien
Supprimer un lien
Fin du mouvement
Il vous reste 13 secondes

Figure A2

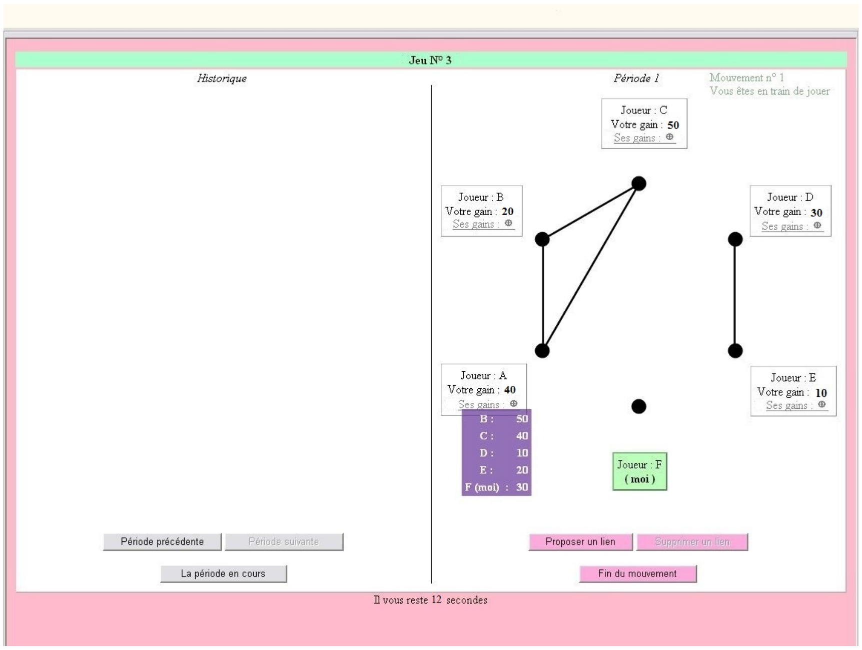


Figure A3

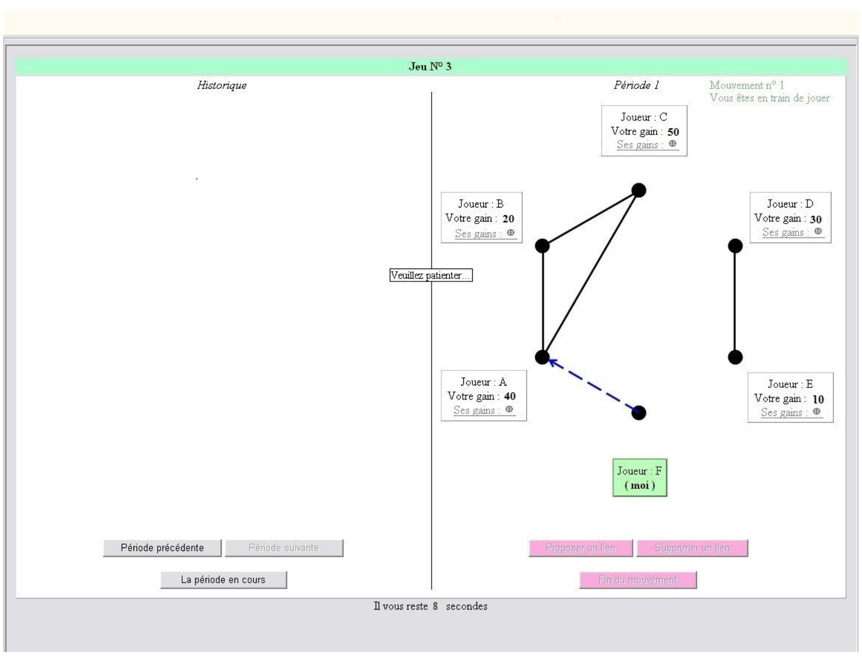


Figure A4

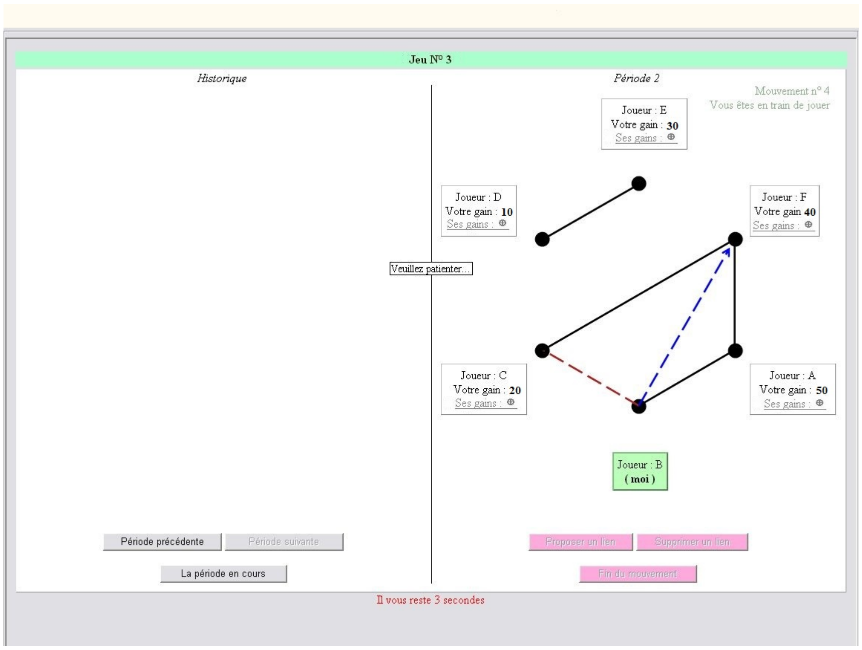


Figure A5

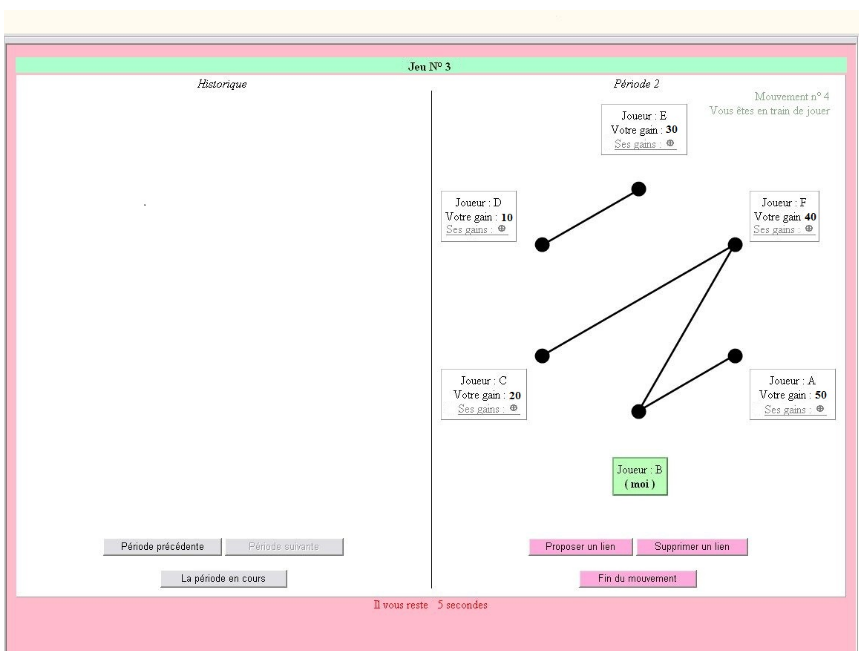


Figure A6

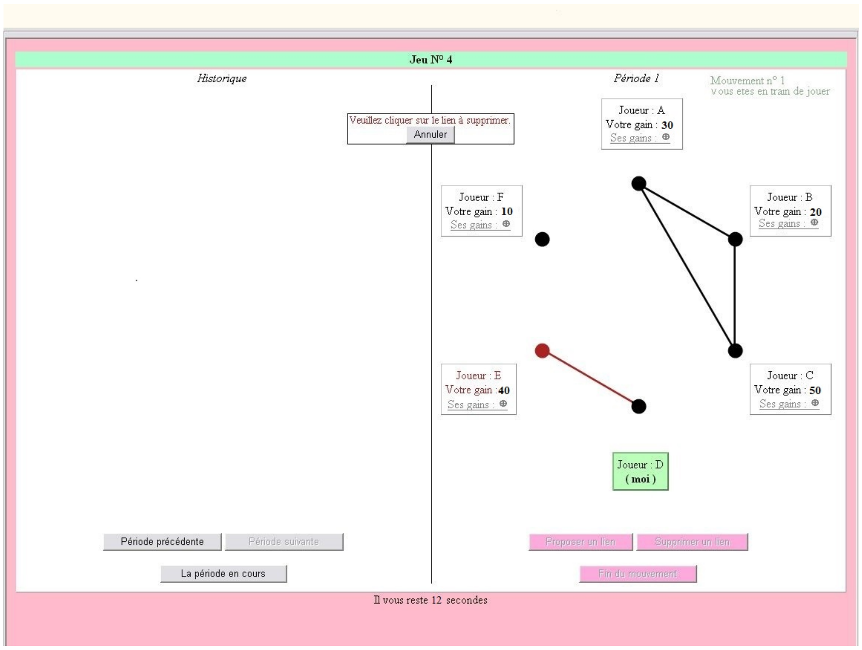


Figure A7

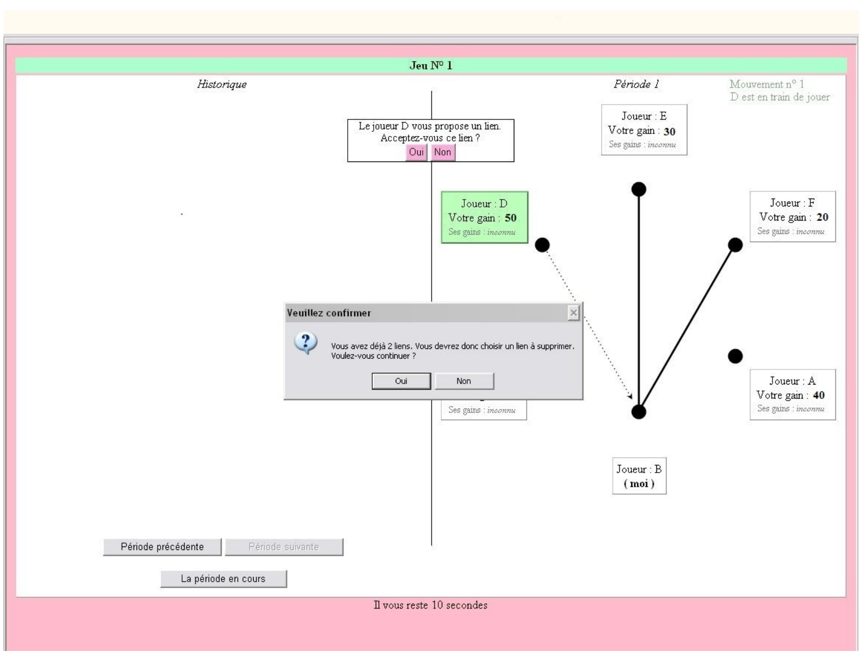


Figure A8

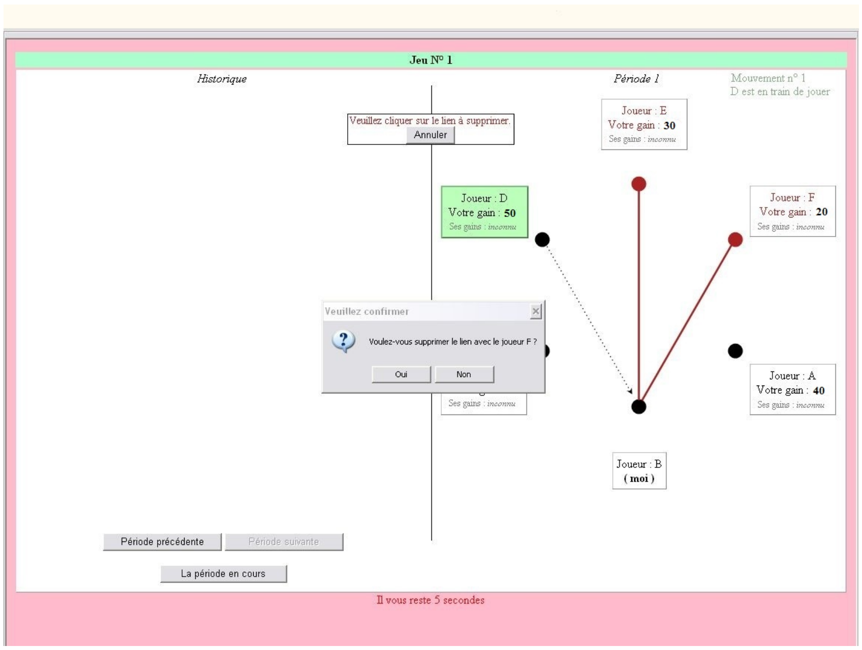
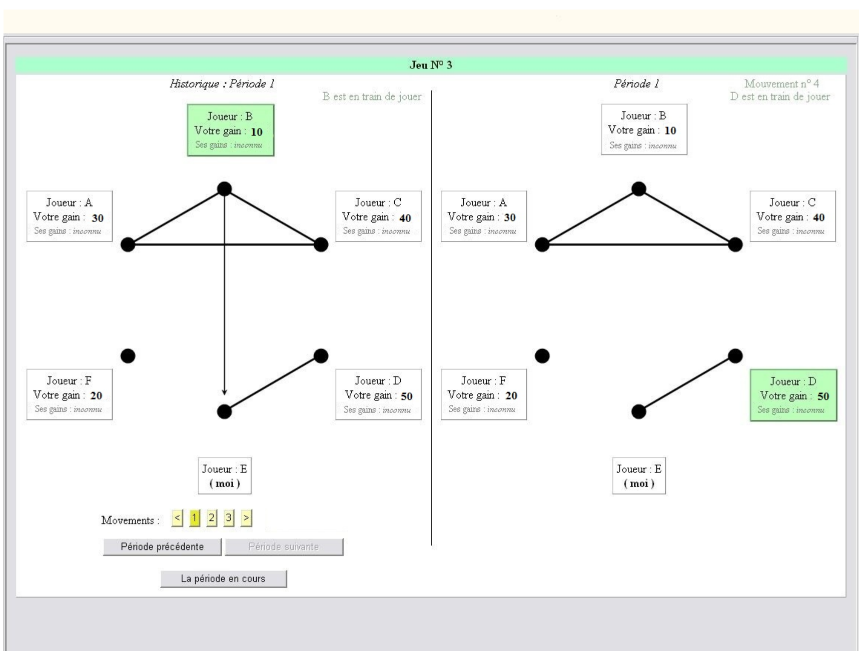


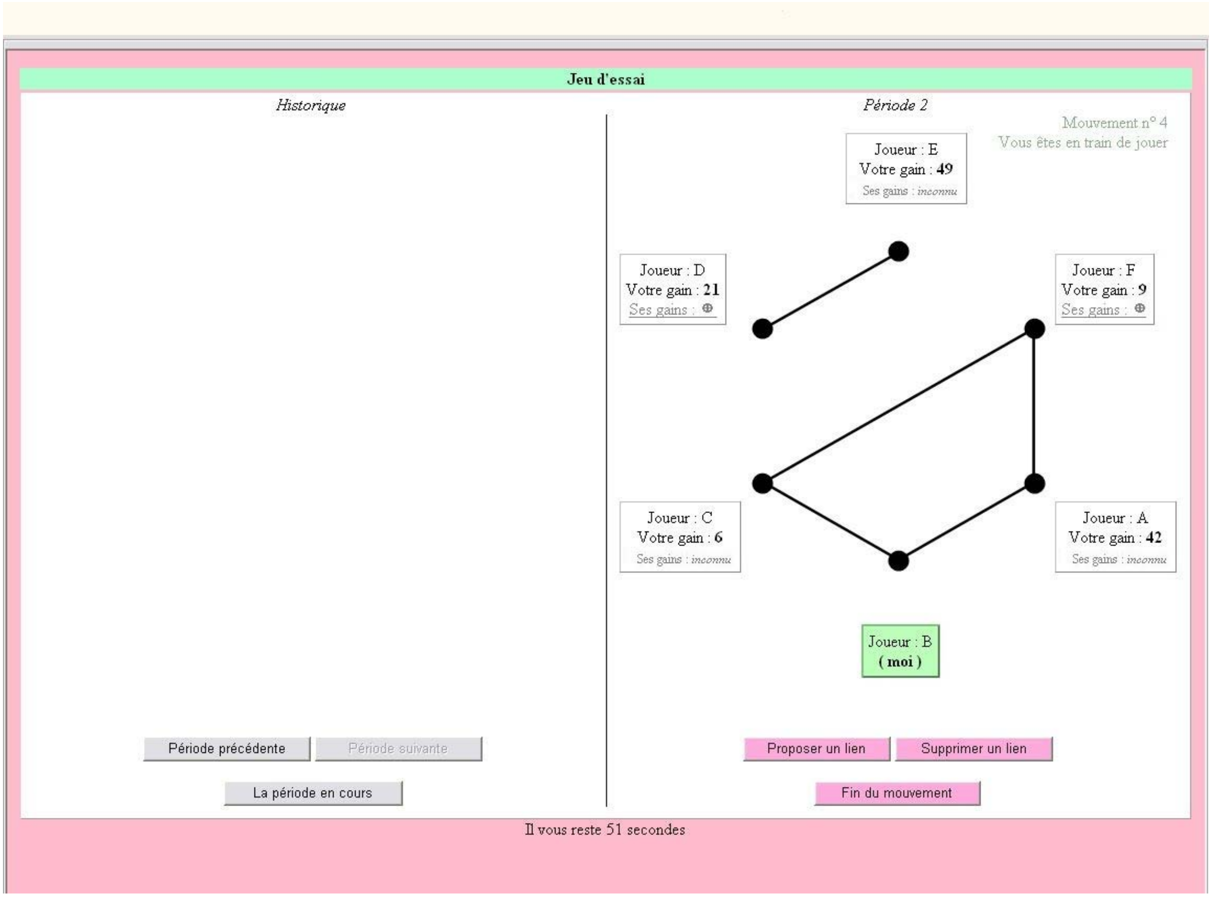
Figure A9



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.