Global versus local interaction in coordination games: an experimental investigation♣

Kene Boun My [a], Marc Willinger [b, *], Anthony Ziegelmeyer [c]

[a, c] BETA-*Theme*, Université Louis Pasteur, 61 avenue de la Forêt-Noire, 67085 Strasbourg, France

[b] Institut Universitaire de France, BETA-*Theme*, Université Louis Pasteur, 61 avenue de la Forêt-Noire, 67085 Strasbourg, France

Abstract. We study experimentally the outcome of a 50 periods repetition of a two-player coordination game, which admits two-pure strategy Nash equilibria that are Pareto-ranked: a payoff-dominant equilibrium and a risk-dominant equilibrium. The experiment consists of a 2x3 factorial design, with two different matching rules –global an local interaction–, and three sizes for the basin of attraction of the risk-dominant equilibrium. Under global interaction, each player can be matched in each period with any player in the population. Under local interaction, each player can be matched only with one of his two neighbours. Our results confirm earlier experimental results obtained under global interaction (for a survey see Ochs (1995)). On the contrary, the results contrast sharply with Keser, Ehrhart & Berninghaus (1998), who found that subjects interacting 'locally' with their neighbours around a circle, coordinate mostly on the risk-dominant equilibrium. Moreover, we found no evidence for a faster convergence to an equilibrium under local interaction than under global interaction.

Key words: Coordination games – Experimental economics – Evolutionary game theory – Local interactions

JEL-classification: C92; C72; C73

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* Corresponding author. Tel. : +33 390 41 40 54, fax: +33 390 41 40 50, e-mail: willma@cournot.u-strasbg.fr.

1. Introduction

This paper reports an experiment designed to study the influence of a local interaction structure on equilibrium selection in a coordination game. A 'global interaction' is a situation in which the behaviour of an agent is directly affected by choices of all other agents in the population. Conversely, interactions are 'local' if agents take into account only the information coming from a strict subset of the population, that is, if only choices of a small group of people are relevant whenever an individual performs his or her decisions. The assumption of 'local interactions' implies the introduction of a spatial dimension in the economy (Kirman (1994)). Agents are physically distributed in some spatial environment and interactions are modelled by means of the distances between agents. The distance between two agents might reflect a geographic characteristic or different socio-economic characteristics of agents themselves. In recent years, models with 'local interactions' have been applied to many economic contexts, such as, for instance, regional economics (Krugman (1994)), technological adoption (Allen (1982a)) or the diffusion of information and the contagion of opinions (Allen B. (1982b)).

The reference treatment is a *Global Interaction* treatment in which subjects interact globally. We compare the results of 12 groups of the *Global Interaction* treatment with the results of 12 groups of the *Local Interaction* treatment. Under global interaction, a player can be matched with any other player in the population, while under local interaction a player can be matched only with players belonging to a subset of players within the whole population. Although under local interaction each player interacts only with the players of his neighbourhood, he interacts indirectly with all the players of the population, because neighbourhoods are overlapping. Each player is therefore also affected by decisions taken by players who do not belong to his own neighbourhood and his own decisions also affect players outside his neighbourhood. We consider a 2x2 symmetric coordination game with two symmetric, strict Nash equilibria and a mixed Nash equilibrium. The two pure-strategy Nash equilibria are Pareto-ranked: one is a *payoff-dominant* equilibrium and the other one is a *risk-dominant* equilibrium[1] in the sense of Harsanyi & Selten (1988). A game with this structure is commonly referred to as a S*tag Hunt game*. Which equilibrium will be selected is a matter of considerable debate since all strict Nash equilibria survive any of the established refinement tests. Therefore, and while the mixed-strategy equilibrium is commonly dismissed, the literature does not provide a clear conclusion as to which of the two pure-strategy equilibria will be selected.

In this paper we contrast previous experimental findings under global interaction with new experimental data on local interaction. In contrast to Keser et al. (1998), our experiment relies on the same size of population of 8 subjects in both the *Global Interaction* treatment and in the *Local Interaction* treatment. In the local interaction structure subjects are spatially distributed on a circle and each one interacts with his adjacent neighbours. We compare the two interaction conditions for three different payoff structures with increasing attractiveness for the risk-dominant equilibrium. Our experimental results weakly support the prediction that under local interaction risk-dominance is the dominant outcome. Indeed, not all the subject groups interacting in the *Local Interaction* treatment did coordinate on the less risky equilibrium, even if more coordination on the payoff-dominant equilibrium is observed in the *Global Interaction* treatment. Moreover, this difference between the two interaction structures is not statistically significant. In this respect, this conclusion contrast sharply with the previous experimental result obtained by Keser et al. (1998) for different population sizes between the local and the global interaction conditions. Nevertheless, we observe that when the risk-dominant equilibrium becomes more attractive, the population "converges"[2] more frequently towards that outcome. Our results also show that "convergence" is not faster under local interaction than under global interaction.

The balance of the paper is as follows. In the next section we survey some theoretical and experimental litterature concerning equilibrium selection. Section 3 introduces the structure of the

[1] The risk-dominant equilibrium is the equilibrium with the largest Nash product, that is, the equilibrium for which the product of the deviation losses is largest.
[2] What is meant by convergence is defined in section 6.3.

game and section 4 describes the matching rules used in the experiment. In section 5 we present the practical procedures. Our results are commented in section 6. Final comments conclude.

2. Some theoretical and experimental literature on the coordination problem

2.1 Theory

We distinguish between the "classical" theories as opposed to the evolutionary theories. Among classical theories, based on models of substantively rational agents, a few do discriminate between the two strict Nash equilibria of such a game (e.g. Harsanyi & Selten (1988), Carlsson & Van Damme (1993), Harsanyi (1995)). Harsanyi & Selten (1988) rely on collective rationality to predict payoff dominance. Carlsson & Van Damme (1993) predict the risk-dominant equilibrium, on the ground that it is robust to a specific type of uncertainty about payoffs. More recently, Harsanyi (1995) revised his position and proposed a new theory of equilibrium selection that relies only on risk dominance as a criterion for choosing among different equilibria. He claimed that the new theory has a much "higher degree of theoretical unity and of direct intuitive understandability", compared to Harsanyi & Selten (1988). Theories which rely on eductive reasoning neglect complicated learning processes that induce equilibrium and therefore they neglect also the history of the process. While classical theories consider only global interaction structures, evolutionary game theory studies both global and local interaction structures. We take therefore as a reference the predictions of evolutionary game theory.

Evolutionary models put forward learning and adaptive behaviour as important features for understanding the strategic choices in a game where players gain experience. Theories based on deterministic dynamics, such as myopic best response dynamic, predict history-dependent equilibrium selection and predict either the payoff-dominant or the risk-dominant equilibrium, depending on the basin of attraction which contains the initial state. Kandori, Mailath & Rob (1993) (henceforth KMR) and Young (1993) reconsidered the learning dynamics, and showed that the addition of a small mutation probability, changes significantly the result of the deterministic dynamics. Stochastic models predict that the limit distribution will concentrate all the probability mass on the risk-dominant equilibrium. Robson & Vega-Redondo (1996) showed that the matching rule of the players may affect the equilibrium outcome. Under random rematching in each period, the payoff-dominant equilibrium will be selected. In these models, the relative sizes of the basins of attraction strongly affect the outcome. This result, however, is weakened if one takes into account other factors, such as the "strength of learning". Binmore & Samuelson (1997) showed that by taking into account this factor, either of the two equilibria will be reached. Finally, Bergin & Lipman (1996) showed that any refinement effect obtained by adding small mutations, as in KMR (1993), is solely due to restrictions on how mutation rates vary across states. They show that virtually any outcome can be obtained, in the limit as the probability of a mutation approaches zero, if in the process the relative probabilities of the strategies to which a mutation switches a player can approach zero or infinity. Besides, some authors studied the impact of local interactions.

Berninghaus & Schwalbe (1996) consider a deterministic interaction model in which each player interacts only with a subset of the population. In their model, risk-dominance, as a selection criterion, is stronger than Pareto superiority. Ellison (1993), who extended KMR's (1993) model to local interactions, also showed that the risk-dominant equilibrium is always selected in the long-run. Blume (1993) studied the play of 2 x 2 games in an infinite two-dimensional lattice, in which agents deviate from their best reply strategy with a probability that depends on the prospective loss in payoff from such a deviation. Blume (1993) considers a log linear response model with parameter $\beta > 0$ and establishes that when the log linear strategy revision approaches the best-reply rule ($\beta \to \infty$), the limit distribution puts probability one on the risk-dominant convention as in the uniform error model. Models of local interactions have also established that "convergence" to the equilibrium is faster under local interactions. Starting from an initial state where most of the players adopt the payoff-dominant action, and for a given rate of mutation, the expected waiting time before all the players adopt the risk-dominant action, is much lower under local interaction than under global interaction.[3] Therefore, under global interaction "..play should exhibit great inertia with a historically determined equilibrium repeated over and over again.", and under local interaction, "…evolutionary forces will be a powerful determinant of play…"[4] (Ellison (1993)). This implies that in an experiment with a finite number of periods of play, under the assumption of best-reply stochastic dynamics, we should observe much more risk-dominant outcomes than payoff-dominant outcomes under local interaction. On the contrary, depending on the payoff structure of the stage game, as much payoff-dominant outcomes as risk-dominant outcomes can be observed under global interaction.

2.2 Previous experiments

Because there is no single theoretical prediction, coordination games have been extensively studied by experimentalists under global interaction (for a survey see Ochs (1995)). The available evidence can be summarised as follows : although the coordination problem is solved by the repeated interaction between subjects, i.e. disequilibrium outcomes are rare, strategic uncertainty leads to coordination failure, i.e. convergence is towards the inefficient equilibrium outcome. Experiments have also shown that factors which are irrelevant according to classical theories affect the outcome. For example, Van Huyck, Battalio & Beil (1990) (henceforth VHBB) observed in a finitely repeated 'weakest link' game[5], that the larger the number of players, the greater the chance that players will end up coordinating on the least profitable equilibrium[6]. More recently, experimental studies sought to identify conditions under which evolutionary game theory adequately characterises observed play in the repeated Stag Hunt game. Battalio, Samuelson & Van Huyck (1997) provide a comprehensive summary about human behaviour in Stag Hunt games

[3] By assuming pairwise asymmetric information structures, Durieu & Solal (1999) rule out cycles in Ellison's deterministic dynamics and reduce the expected first passage time from one Nash equilibrium to another in stochastic dynamics.
[4] More details concerning the expected waiting time under both interaction structures will be given afterwards.
[5] A 'weakest link' game is a pure coordination game in which individual payoffs are partly determined by the minimum effort chosen in the population.

under global interaction structures: 1) non-equilibrium outcomes are rare, 2) in the first period of play the payoff-dominant strategy is generally the modal choice, 3) the final outcome of the game is generally accurately predicted by the location of the initial outcome in a particular basin of attraction. The experiment of Keser, Ehrhart & Berninghaus (1998) showed that if the interaction structure is local the equilibrium selection is drastically modified. If all players are located around a circle, with each player having 2 neighbours (the adjacent players), the strategy choices converge towards the risk-dominant equilibrium. Moreover, in their fixed group treatment without local interaction, they observed that the payoff-dominant equilibrium was more often selected than the risk-dominant equilibrium.

3. The coordination game

The stage game is a 2x2 symmetric game illustrated in figure 1, where each player has to choose strategy X or strategy Y. If both players choose X, then both get a payoff of a; if both players choose Y, then both get d. If one player chooses X while the other chooses Y, then the former player gets c while the latter player gets b. We consider the case where $a > b$ and $d > c$ so that the stage game has two pure-strategy Nash equilibria: (X,X) and (Y,Y). We also require that $d – c > a – b$, which implies that (Y,Y) is the risk-dominant equilibrium. Finally, we assume that the two equilibria are Pareto-ranked, and that $a > d$, which implies that (X,X) is the payoff-dominant equilibrium.[7]

	X	Y
X	**a, a**	**c, b**
Y	**b, c**	**d, d**

Figure 1: The stage coordination game.

[6] Crawford (1991) gives an evolutionary interpretation of these experimental results and Carlsson & Ganslandt (1998) by perturbing symmetric coordination games provide a theoretical foundation for VHBB's results.

[7] The stage game has also an equilibrium in mixed strategies in which each player chooses strategy X with probability $k^* = (d - c) / (a + d – b - c)$.

Defined like this, this stage game is commonly referred to as the Stag Hunt game and poses the potential conflict between efficiency and security. Although, strategy X might yield the highest payoff (a) if the opponent chooses also X, it is risky since it yields the lowest payoff (c) if the opponent chooses the safe strategy Y. More precisely, one strict Nash equilibrium risk dominates the other if, after a normalisation of payoffs which preserves best-reply correspondences and dominance relations between strategies, it strictly Pareto dominates the second (see Weibull (1995)). For example, the payoff matrix of figure 1 can be normalised in the following manner:

	X	Y
X	**a - b, a - b**	**0, 0**
Y	**0, 0**	**d – c, d - c**

After such a normalisation of payoffs, the strict Nash equilibrium (X,X) appears no longer attractive since d – c > a – b.

In the experiment we used three different payoff matrices in both treatments. Thus, we have a 2x3 factorial design, with 2 different matching rules and 3 different payoff matrices. Figure 2 shows the parameter values considered in the experiment.

	X	Y
X	50, 50	0, 25
Y	25, 0	30, 30

i

	X	Y
X	50, 50	0, 30
Y	30, 0	40, 40

ii

	X	Y
X	45, 45	0, 35
Y	35, 0	40, 40

iii

Figure 2: Parameter values used in the experiment.

Let k be the probability with which each player chooses strategy and define k* as the value of k for which a player is indifferent between choosing strategy Y and choosing strategy X, i.e. k* is the value of k for which there is a mixed-strategy equilibrium. k* depends on the payoff matrix: k* = 0.54 for payoff matrix i, k* = 0.67 for payoff matrix ii, and k* = 0.80 for payoff matrix iii. In fact, Y is a k*-dominant strategy which implies that if k* = 1 then strategy Y weakly dominates strategy X. Moreover, in the normalised payoff matrix, the gain resulting from strategy profile (Y,Y) is k* / (1-k*) times the gain resulting from strategy profile (X,X). In other words, the greater k*, the more attractive is the risk-dominant equilibrium.

From the evolutionary perspective, the risk-dominant equilibrium has the larger basin of attraction under the best-reply as well as the replicator dynamics.[8] Under global interaction k* is commonly referred to as the "separatrix" because it divides the state space into two basins of attraction: the basin of attraction of the payoff-dominant equilibrium and the basin of attraction of the risk-dominant equilibrium. Each basin of attraction has an absorbing state in which all players adopt the same strategy[9]. Henceforth we note Y° the steady state in which all players adopt strategy Y and X° the steady state in which all the players adopt strategy X. Moving from payoff matrix i to payoff matrix ii and iii implies that, under global interaction, we allow more and more initial conditions to converge to the state Y° under deterministic dynamics. On the contrary, when each player interacts only with two neighbours the value of k* becomes irrelevant since the basin of attraction of X° contains only one state, X° itself. Thus, under the local interaction condition, the magnitude of k* has no impact on the relative sizes of the basins of attraction and we therefore expect the likelihood of observing Y° to be high. Nevertheless, as noted by Fudenberg & Levine (1998), "..this implicitly supposes a more-or-less uniform prior over possible initial positions".

4. Matching rules

We introduce now two different matching rules that we used in our experiment.

4.1 The *Global Interaction* treatment

The stage coordination game is repeated 50 times by the same group of 8 players. Under global interaction, each player in the population can be matched with any of the 7 other players in the population. However, his actual payoff depends only on the action taken by his actual opponent. At the end of each round, each player is informed about the distribution of decisions in his group for the current round. No information about the individual decisions of the other players is given. A player's payoff is determined by the sum of his payoffs over all 50 rounds. The players have complete information about the game. They know each player's payoff function (the same for each player) and that the game ends after 50 repetitions.

In this treatment, under deterministic dynamics, the basins of attraction of the two strict Nash equilibria have the same size when the stage game relies on payoff matrix i. For the two others matrices, payoff matrix ii and payoff matrix iii, the risk-dominant equilibrium has the largest basin of attraction. Thus, KMR (1993) and Young (1993) predict that, for payoff matrix ii and payoff matrix iii, the limit distribution concentrates all of its probability on the risk-dominant equilibrium.

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[8] Due to integer problems such a result is true only for large populations of players under global interaction and for small neighbourhoods under local interaction.

[9] Be aware that the mixed-strategy equilibrium can not be an absorbing state in a symmetric game.

4.2 The *Local Interaction* treatment

Like under global interaction, the stage coordination game is repeated 50 times by the same group of 8 players. Under local interaction, each player in the population can be matched only with one of his neighbours. In our experiment we considered only neighbourhoods containing two players. The different neighbourhoods are arranged on a circle design, so that the neighbourhood of a given player contains his two adjacent players. Figure 3 describes the interaction structure (a similar figure has been used in the instructions of the *Local Interaction* treatment in order to make the subjects aware of the local interaction condition). In this circle design, player 1 plays either with player 2 or with player 8. Player 2 interacts either with 1 or with player 3, and so on. Player 1's payoff depends on his own choice and on the choice of his actual opponent either player 8 or player 2. At the end of each round, each player is informed about the distribution of his neighbours' choices for the current round. But he is neither informed about the individual decisions of his neighbours, nor about his neighbours' neighbours' decisions. Each player's final payoff depends on the cumulative payoff over all 50 rounds. Players have complete information about the game. They know each player's payoff function (the same for everyone), they know that their neighbours also interact with other neighbours, they know that they are allocated around a circle of 8 players, and that the game ends after 50 repetitions.

In the *Local Interaction* treatment, whatever the payoff matrix considered, the risk-dominant equilibrium has the same largest basin of attraction under best-reply deterministic dynamics. Consequently, Ellison (1993) and Berninghaus & Schwalbe (1996) predict the risk-dominant equilibrium as an outcome in all cases.

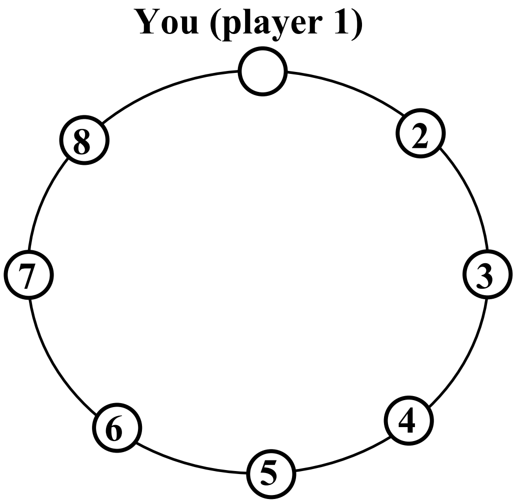

Figure 3: Local interactions on the circle.

Note that our experimental design is not specifically based on one of the models reviewed in the introduction, for two reasons. First, there is no reference model available for this literature. The existing models make different assumptions about behavioral rules, matching rules or mutation probabilities. Furthermore, except for Ellison (1993), the models based on global interaction cannot be easily compared to those which study local interaction. Finally, all models are based on a large population and a very large number of periods, two features which cannot be reproduced in the lab. Second, our aim is essentially to study how the interaction structure affects coordination in a simple game. In this respect, those models are not very useful since their primary focus is the long run outcome of the interaction process.

Nevertheless, our experimental design is able to provide some useful insights about the aggregate behavior of a population of human players interacting in a controlled environment. As in the case of market experiments, the primary interest of the experimental methodology is to discover which factors affect the outcome of the process and which factors play a negligible role. In this respect we are essentially interested in the influence of the interaction structure and the payoff matrix on the aggregate outcome of the interaction process.

As previously noted, the easiest way to compare our results between both interaction structures and between the different payoff matrices will be to rely on best-reply dynamics with a uniform error model as considered by KMR (1993) and Ellison (1993). In such settings, we have clear results concerning the impact of k*, the impact of the interaction structure and the speed of convergence of the interaction process. In this respect, we will mainly rely on this framework in order to evaluate our experimental results.

5. Practical Procedures

The experiment was run on a computer network[10] in Spring 1997, using 192 inexperienced students, at the Laboratory of Experimental Economics of Strasbourg (LEES[11]). The subjects were recruited by phone from a pool of 600 students. Subjects were students from various disciplines. Twelve sessions were organised, with 2 groups of 8 subjects per session. The experiment consisted of a 2x3 factorial design {global interaction, local interaction}x{k* = 0.54, k* = 0.67, k* = 0.80} with 4 observations per cell. Subjects were randomly assigned to a group of 8 players, to play a 50-fold repetition of the stage coordination game, the stage game being either based on payoff matrix i, payoff matrix ii or payoff matrix iii. Each subject was seated at a computer terminal, which was physically isolated from other terminals. Communication, other than through the decisions made, was not allowed. The subjects were instructed about the rules of the game and the use of the computer program through written instructions (available upon request), which were also read aloud by a research assistant. A short questionnaire was submitted to the subjects to check their understanding of the instructions, followed by two training periods, during which subjects were told that they would simply play "against" a computer program.[12] After each period

[10] Based on an application developed by K. Boun My (1997) designed for Visual Basic.
[11] BETA, Université Louis Pasteur, Strasbourg, France.
[12] In pilot sessions we observed that the initial period of play in the experiment, was strongly influenced by the outcomes during the training sessions when training sessions involved subjects playing against each other. If they coordinated on X during the training sessions, they tended to do the same in period 1 of the experiment, and similarly when the coordinated on Y. Therefore, we tried to neutralize the training sessions by letting them play "against" the computer, and announcing in advance the computer's "choice".

subjects were informed about the individual number of points gained for that period. They were also informed about the number of points earned by the other player, with whom they interacted, the decision that he had taken in that period, the number of players of their neighbourhood who played X and the number of players of their neighbourhood who played Y. The accumulated number of points since the beginning of the experiment was on permanent display. Rewards were counted in points and converted at the end of the experiment into cash (1 point = 0.04 Francs). Subjects were also paid a show-up fee of 30 Francs that was added to their cash earnings for the experiment at the end of the session.

6. Results

We present the results with respect to the three stylised facts observed under global interaction and summarised by Battalio et al. (1997): non-equilibrium outcomes are rare, the modal first period outcome is the payoff-dominant strategy, and convergence is accurately predicted by the first period state. Besides, we analyse our experimental results by comparing them to, either deterministic or stochastic, best-reply dynamics. Indeed, clear predictions exist in such a theoretical framework concerning at once the outcome of the interaction process and the speed of "convergence". Thus, we compare the myopic best reply rates between both matching rules. Note that subsection 6.1 summarizes results concerning the coordination problem at the individual level, whereas subsection 6.2 and 6.3 deal with the outcome of the process constituted by the whole group of subjects. Although we have few independent observations (4 groups for each payoff matrix both in the *Global Interaction* treatment and in the *Local Interaction* treatment) we shall indicate the significance level of the comparison between the two treatments for each payoff matrix or between two payoff matrices in the same treatment.[13] Appendix A presents the time path of the number of subjects who choose X for each group.

6.1 Equilibrium outcomes

Tables 1 summarises the data for the 50 periods. For both interaction structures, the first column identifies the groups, the second column indicates the overall proportion of Nash equilibria observed in the 50 periods, and the last column indicates among the Nash equilibria the overall proportion of Pareto outcomes (X°). Each group label has three items. The letter refers to the interaction structure (Global or Local), the first number refers to the payoff matrix (0.54, 0.67 or 0.80) and the last number refers to the group number.

Global Interaction			*Local Interaction*		
Group	Nash	Pareto	Group	Nash	Pareto
G54.1	94%	99%	L54.1	77%	93%
G54.2	90%	98%	L54.2	78%	91%
G54.3	84%	99%	L54.3	80%	96%
G54.4	84%	99%	L54.4	76%	97%

(a): k* = 0.54.

Global Interaction			*Local Interaction*		
Group	Nash	Pareto	Group	Nash	Pareto
G67.1	100%	100%	L67.1	93%	1%
G67.2	95%	100%	L67.2	77%	99%
G67.3	86%	9%	L67.3	97%	100%
G67.4	87%	100%	L67.4	74%	3%

(b): k* = 0.67.

Global Interaction			*Local Interaction*		
Group	Nash	Pareto	Group	Nash	Pareto
G80.1	65%	20%	L80.1	92%	4%
G80.2	80%	98%	L80.2	83%	6%
G80.3	86%	16%	L80.3	60%	75%
G80.4	88%	100%	L80.4	80%	9%

(c): k* = 0.80.

<u>Table 1</u>: Overall proportion of Nash equilibria and payoff-dominant (Pareto) equilibria.

[13] All comparison are tested with the Wilcoxon-Mann-Whitney test and we set the significance level at 5 %.

Under global interaction the average proportion of Nash equilibria over the three payoff matrices is equal to 86.58 % and under local interaction it is equal to 80.58 %; this difference is not statistically significant. Concerning the proportion of Pareto outcomes among Nash equilibria, the average proportion over the three payoff matrices is equal to 78.17 % under global interaction and it is equal to 56.17 % under local interaction; once again, this difference is not statistically significant. For $k^* = 0.54$, there is a high frequency of payoff-dominant equilibria, both under local and under global interaction. The situation is more contrasted for $k^* = 0.67$ and $k^* = 0.80$. In some groups, the payoff-dominant equilibrium is the more frequent, while in others it is the risk-dominant one which is outstanding. More precisely, for $k^* = 0.54$, both the proportion of Nash equilibria and the proportion of payoff-dominant equilibria among the Nash equilibria are significantly larger under global interaction than under local interaction ($p = 0.014$). If $k^* = 0.67$ or $k^* = 0.80$, neither the proportion of Nash equilibria nor the proportion of payoff-dominant equilibria among the Nash equilibria is significantly affected by the type of interactions. Indeed, for $k^* = 0.67$, there are clearly three groups which are close to the payoff-dominant equilibrium under global interaction, while the other one is closer to the risk-dominant solution. For $k^* = 0.80$, there are two groups which are close to the payoff-dominant equilibrium under global interaction, while the two others are closer to the risk-dominant solution. Under local interaction, for $k^* = 0.67$, in two groups there is a high frequency of risk-dominant equilibria, while the remaining groups get closer to the payoff-dominant equilibrium and for $k^* = 0.80$ there are three groups which are close to the risk-dominant equilibrium and the last one is close to the payoff-dominant solution.

Under both types of interaction structures, there is no significant difference in the proportion of Nash equilibria between $k^* = 0.54$, $k^* = 0.67$ and $k^* = 0.80$. However, under local interaction for $k^* = 0.54$ there is a significant larger proportion of payoff-dominant equilibria than with $k^* = 0.80$

(p = 0.014). There is no such a significant difference between k* = 0.67 and the two other values of k*.

Finally, note that as in previous experiments under global interaction, we observe a high rate of equilibrium plays in our *Global Interaction* treatment.

6.2 Initial and Final States

Table 2 compares the initial state, observed in period 1, with the final state, observed in period 50. Previous experiments found that under global interaction are that the modal first period outcome is the payoff-dominant strategy, and that convergence is accurately predicted by the first period state which is in accordance with best-reply deterministic dynamics. Accordingly, we report in table 2 the number of players choosing X in the first period and in the last period for global interaction. Concerning local interaction, since we rely on best-reply dynamics, we have to be more precise. For the local interaction structure, table 2 reports not only the total number of players who chose X in the first and in the last period, but describes also each subject's decision for these periods as a string of X's and Y's. Subjects are arranged in accordance with Figure 3, i.e. the subject who corresponds to player 1 is on the left and the subject who corresponds to player 8 is on the right. This implies that subject 1 has interacted in each period either with the subject who is on his right, i.e. subject 2, or with the subject who is on the right, i.e. subject 8.

Global interaction			Local interaction		
Group	**Period 1**	**Period 50**	**Group**	**Period 1**	**Period 50**
G54.1	6/8	8/8	L54.1	7/8 X**Y**XXXXXX	7/8 XXXX**Y**XXX
G54.2	6/8	7/8	L54.2	8/8 XXXXXXXX	8/8 XXXXXXXX
G54.3	7/8	8/8	L54.3	7/8 XXXXXX**Y**X	8/8 XXXXXXXX
G54.4	7/8	8/8	L54.4	7/8 XXXXX**Y**XX	7/8 X**Y**XXXXXX
G67.1	7/8	8/8	L67.1	3/8 **YY**X**YY**X**Y**X	0/8 **YYYYYYYY**
G67.2	6/8	8/8	L67.2	7/8 XXXXXXX**Y**	8/8 XXXXXXXX
G67.3	5/8	0/8	L67.3	8/8 XXXXXXXX	8/8 XXXXXXXX
G67.4	8/8	8/8	L67.4	4/8 XX**YY**X**Y**X**Y**	0/8 **YYYYYYYY**
G80.1	5/8	0/8	L80.1	2/8 **YYYYYY**XX	0/8 **YYYYYYYY**
G80.2	7/8	7/8	L80.2	5/8 X**YY**X**Y**XXX	0/8 **YYYYYYYY**
G80.3	6/8	1/8	L80.3	7/8 XXX**Y**XXXX	4/8 X**YY**X**Y**X**Y**X
G80.4	7/8	8/8	L80.4	7/8 XXXX**Y**XXX	0/8 **YYYYYYYY**

Table 2: Initial and final states.

As an example, in group G54.1, in period 1, 6 subjects out of 8 played X and two played Y. Our results support the stylised fact that under global interaction the modal first period outcome is the payoff-dominant strategy. Moreover, no significant differences in the number of players choosing X in the first period are observed when comparing different values of k* in our *Global Interaction* treatment.

Changing the interaction rule has little impact on initial conditions. A comparison of both types of interaction structures reveals that no significant difference is observed concerning the number of players choosing X in the first period; this fact is true for each payoff matrix. Besides, no significant differences in the number of players choosing X in the first period are observed when comparing different values of k* in our *Local Interaction* treatment. Let us turn now to the third stylised fact : the final outcome of the game is accurately predicted by the location of the initial outcome in a particular basin of attraction

For the *Global Interaction* treatment we observe that in all cases the final state lies in the same basin of attraction as the initial state. Let us note nX the state where n players have adopted strategy X, n = 0, 1, …, 8, and let D_{Y° be the set of states which belong to the basin of attraction of

Y°, and $D_{X°}$ the set of states which belong to the basin of attraction of X°. For k* = 0.54 we have $D_{Y°}$ = {0X, 1X, 2X, 3X}, $D_{X°}$ = {5X, 6X, 7X, 8X}[14], for k* = 0.67 we have $D_{Y°}$ = {0X, 1X, 2X, 3X, 4X, 5X}, $D_{X°}$ = {6X, 7X, 8X} for k* = 0.67 and for k* = 0.80 we have $D_{Y°}$ = {0X, 1X, 2X, 4X, 5X, 6X}, $D_{X°}$ = {7X, 8X}. Separatrix crossing in rarely observed (one occurs in group G80.1, two occur in group G80.2 and one occurs in group G80.4). Battalio et al. (1997) noted already that such events are rare in experimental data concerning Stag Hunt games under global interaction. Thus, stochastic dynamics, as considered for example by KMR (1993), agree poorly with our observations. Even if convergence in such dynamics often relies on long periods of time, note that for payoff matrix iii the expected waiting time is less than 50 periods as long as the rate of mutation is greater or equal to 0.03.

In our *Local Interaction* treatment things are less in accordance with deterministic best-reply dynamics. Indeed, all states which consist of 7 players choosing X in the first period imply a cycle under these dynamics, in which each player switches from the pareto-dominant to the risk-dominant action and vice-versa. We never observe the emergence of such a cycle. On the contrary, in some cases such an initial state implies convergence to state X°, whereas in an other case it implies convergence to state Y° depending on the payoff matrix. Nevertheless, the larger the value of k* the less players are choosing X in the last period. This result can be explained by the fact that a larger value of k* implies a larger number of initial states in favour of Y° and simultaneously less observed convergence to X° when 7 subjects already played X in the first period. Besides, deterministic best-reply dynamics disagrees with behaviours in groups L54.3 and L67.2. Indeed, in both groups the number of subjects who choseY declines between the first and the last period of interactions. Such a decline is not predicted under local interaction with two neighbours. Finally, concerning the number of players choosing X in the last period, no significant difference is observed between both types of interaction structures, for either payoff matrix. Again our experimental results under local interaction are in contradiction with stochastic dynamics, as

[14] The state {4X} is part of a two-states cycle in which each player switch from the pareto-dominant to the risk-

considered for example by Ellison (1993). In fact, the expected waiting time is independent of the magnitude of k* when each player has only two neighbours and is generally less than 50 periods even if we allow for very small mutation rates. Thus, the process should rapidly converge to state Y° whatever the payoff matrix and whatever the initial state.

6.3 Convergence

To study the convergence within the population with respect to the steady states X° and Y°, we take the point of view of the stochastic dynamics which determines the most likely equilibrium. We therefore take into account a tolerance bound of 1/8: if, for some period, at least 7 players adopt the same strategy for all the remaining periods, we assume that convergence has been reached.[15] We define this period as the convergence period. We also consider a weaker indicator, corresponding to the number of periods for which at least 7 subjects chose the same strategy, since in many cases at least 7 subjects chose the same strategy before the convergence period. Table 3 summarizes the results with respect to convergence. For both matching rules, the first column identifies the groups, the second column shows the convergence period with its associated outcome (X° or Y°), and the last column indicates the number of periods spent by the process inside the convergence bound (CB), i.e. at least 7 players adopt the same strategy in each of these periods. Although there is no convergence observed for the L80.3 group, for the purpose of statistical analysis, we set the convergence period at 51 and the number of periods spent by the population within the CB at 0. Appendix B presents the same analysis with a larger tolerance bound of 2/8.

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dominant action and vice-versa.

Global Interaction			*Local Interaction*		
Group	Convergence Period	# of periods inside CB	Group	Convergence Period	# of periods inside CB
G54.1	5 (X°)	46	L54.1	49 (X°)	28
G54.2	11 (X°)	43	L54.2	38 (X°)	27
G54.3	41 (X°)	43	L54.3	29 (X°)	38
G54.4	15 (X°)	41	L54.4	50 (X°)	35

(a): k* = 0.54.

Global Interaction			*Local Interaction*		
Group	Convergence Period	# of periods inside CB	Group	Convergence Period	# of periods inside CB
G67.1	1 (X°)	50	L67.1	22 (Y°)	44
G67.2	8 (X°)	47	L67.2	31 (X°)	41
G67.3	9 (Y°)	42	L67.3	1 (X°)	50
G67.4	28 (X°)	43	L67.4	42 (Y°)	31

(b): k* = 0.67.

Global Interaction			*Local Interaction*		
Group	Convergence Period	# of periods inside CB	Group	Convergence Period	# of periods inside CB
G80.1	43 (Y°)	16	L80.1	12 (Y°)	40
G80.2	43 (X°)	43	L80.2	38 (Y°)	33
G80.3	15 (Y°)	36	L80.3	-	-
G80.4	22 (X°)	48	L80.4	31 (Y°)	33

(c): k* = 0.80.

Table 3: Convergence analysis (tolerance bound of 1/8).

[15] Although the procedure is somehow arbitrary, it is reasonable to admit that convergence is reached if deviations from a given steady state are small (see e.g. D. Friedman (1996)).

For each payoff matrix we observe that on average convergence takes more periods under local interaction than under global interaction. However, for none of the payoff matrices is this difference statistically significant. We observe also that the average number of periods spent by the population within the CB is larger under global interaction than under local interaction for each payoff matrix. For $k^* = 0.54$, the population spends significantly more periods at equilibrium under global interaction than under local interaction ($p = 0.014$). For $k^* = 0.67$ and $k^* = 0.80$ there is no statistically significant difference with respect to the time spent at equilibrium.

Again, we can remark that stochastic best-reply dynamics contrast sharply with our experimental results. Even when these dynamics are in accordance with the observed final state, the number of periods spent around this well predicted state (Y°) is not higher under local interaction than under global interaction. In the next section we try to give some insights concerning this disturbing fact.

6.4 Myopic best reply

Myopic best response is one of the central hypotheses for the evolutionary learning dynamics analysis (see for example KMR (1993) or Ellison (1993)). It assumes that players react to the distribution of play in the previous period, capturing the intuitive notion that players react myopically to their environment. We studied whether the decisions of the players satisfy the myopic best response by measuring the best reply rate (BRR). In order to do that, we counted for each player the number of decisions which were equivalent to a myopic best reply and made the average over the 50 periods and all the players in the group. Table 4 shows that in all games subjects have a significant tendency to take decisions in accordance with the myopic best reply prediction with respect to the proportion of the population (*Global Interaction* treatment) or of their neighbourhood (*Local Interaction* treatment).

Global Interaction						*Local Interaction*					
Group	BRR	Group	BRR	Group	BRR	Group	BRR	Group	BRR	Group	BRR
G54.1	92%	**G67.1**	100%.	**G80.1**	71%	**L54.1**	72%	**L67.1**	96%	**L80.1**	93%
G54.2	84%	**G67.2**	92%	**G80.2**	83%	**L54.2**	71%	**L67.2**	71%	**L80.2**	89%
G54.3	80%	**G67.3**	90%	**G80.3**	84%	**L54.3**	76%	**L67.3**	95%	**L80.3**	56%
G54.4	79%	**G67.4**	81%	**G80.4**	91%	**L54.4**	76%	**L67.4**	83%	**L80.4**	88%

Table 4: Best reply rates (BRR).

One observes slightly lower rates of best reply under local interaction than under global interaction. Indeed, for each payoff matrix, the average rate of BR over all 4 groups is larger under global interaction than under local interaction which implies that the average rate of BR over all 12 groups is larger under global interaction (85.58 %) than under local interaction (80.50 %). Nevertheless, the only significant difference is observed for k* = 0.54 where the average rate of BR is significantly larger under global interaction (83.75 %) than under local interaction (73.75 %) (p = 0.014). From the evolutionary theoretical point of view, all the results discussed in this sub-section are in accordance with the results observed in 6.2 and 6.3. Indeed, we simultaneously observe lower rates of myopic best reply and a lower number of periods spent by the population within the CB under local interaction than under global interaction. Both differences are only statistically significant for k* = 0.54. In the meantime, whereas best-reply dynamics are in accordance with the observed initial and final state in the *Global Interaction* treatment, they contrast sharply with our results in the *Local Interaction* treatment.

7. Concluding remarks

The purpose of our experiment was to compare the outcome of a simple coordination game, when interactions are repeated among players of the whole population (*Global Interaction* treatment) with a context where interactions are restricted to small overlapping neighbourhoods of players

(*Local Interaction* treatment). We compared the outcomes of the two interaction structures for different sizes of the basin of attraction of the risk-dominant equilibrium; k* = 0.54, k* = 0.67 and k* = 0.80. We summarise our results as follows.

Firstly, some of the stylised facts observed in earlier studies on global interaction, are reproduced in our global interaction treatment and two are preserved for local interaction. More precisely, i) non-equilibrium outcomes are rarely observed both under local and under global interaction, ii) the first period modal choice is the payoff-dominant strategy both under local and under global interaction, iii) under global interaction, the first period play determines strongly the steady-state which will be reached, as it generally lies in the same basin of attraction as the initial state.

Secondly, in the local interaction treatment we observe a clear difference between k* = 0.54 and k* = 0.80. Convergence is towards the payoff-dominant steady state for k* = 0.54 and towards the risk-dominant steady state only for k* = 0.80 under local interaction. The larger the basin of attraction of the risk-dominant equilibrium the more we observe convergence to the risk-dominant equilibrium.

Thirdly, there is no evidence in our analysis that convergence is faster under local interaction than under global interaction. On the contrary, for k* = 0.54 the population spent significantly more periods near the equilibrium under global interaction than under local interaction. The most notable difference between both types of interaction structures is with respect to the number of subjects playing X in the final state. There is slightly more convergence to the risk-dominant solution under local interaction for k* = 0.67 and for k* = 0.80.

In accordance with Keser et al. (1998), we find that on average subjects play the myopic best response under global interaction. But in contrast to their result (1998), myopic best reply fits much less our data under local interaction. A possible reason for that is due to the fact that myopic best reply takes only into account past periods of play. It is possible that under local interaction, behaviors wer more forward oriented, in the sense that subjects could have tried to "persuade" their neighbours to play the pareto-dominating strategy by playing themselves that strategy. They could have felt that it is easier to persuade two neighbours rather than 7 persons at a time, even though their neighbours are not isolated from the rest of the population

Note that in our experimental work we have opposed risk-dominance and Pareto-dominance. Nevertheless, (Y, Y) is not only the risk-dominant equilibrium in the three payoff matrices we have considered, but it is also the secure equilibrium. Indeed, action Y always has its minimum payoff greater than action X's minimum payoff. Further work could be devoted to analyse subjects' behavior in a controlled environment where two strict Nash equilibria coexist, one which is Pareto-dominant and risk-dominant and the second one which is the secure equilibrium.

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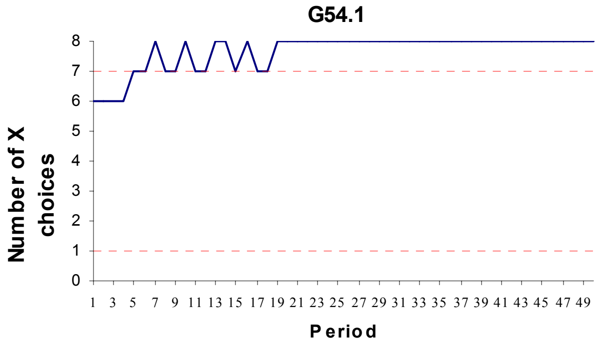
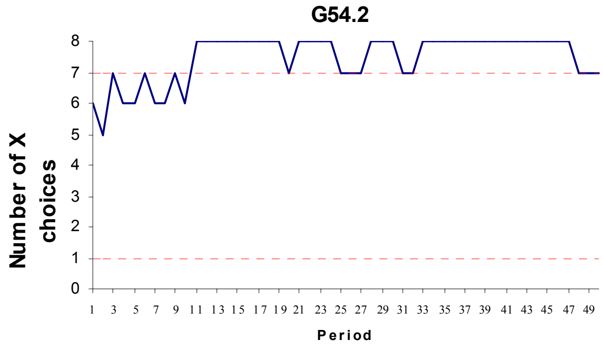
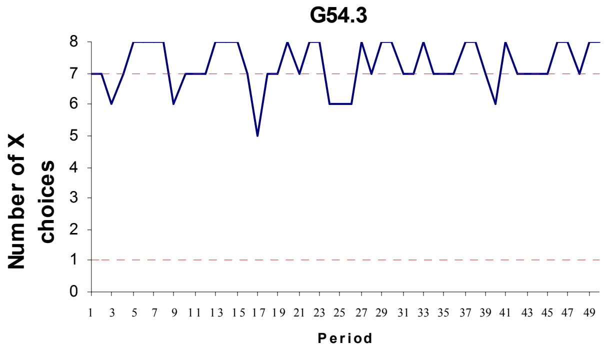
APPENDIX A

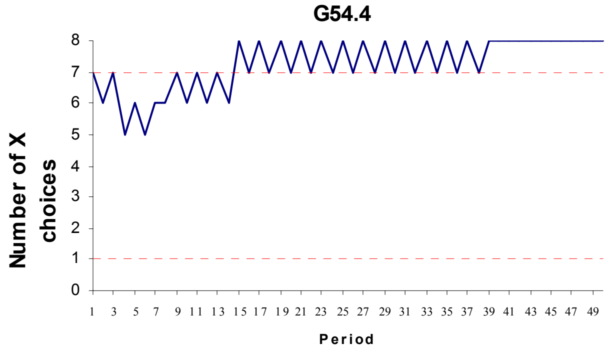
k* = 0.54

Global Interaction

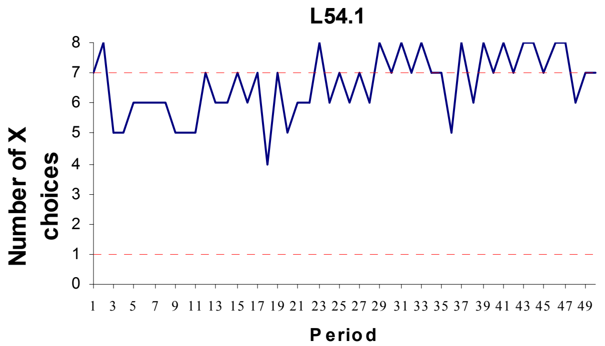


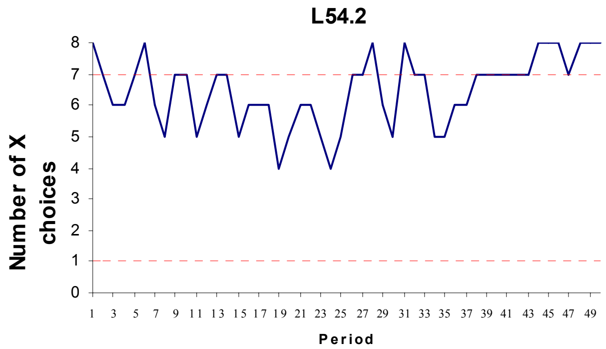


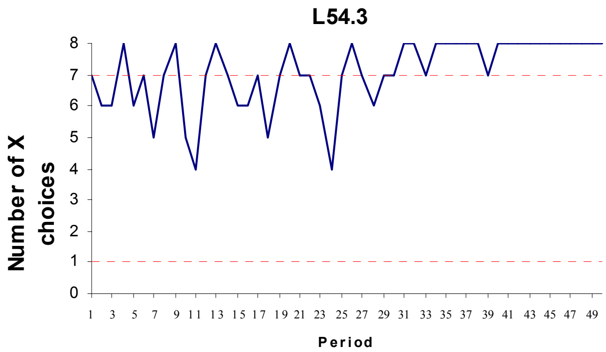


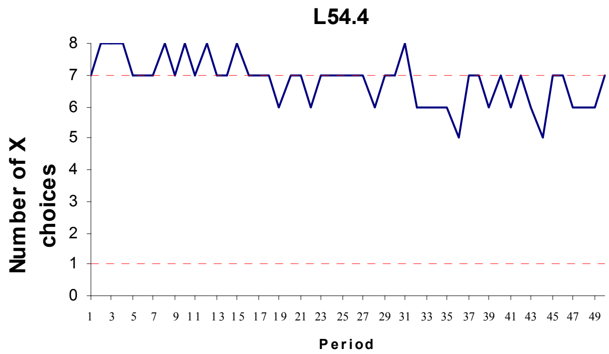


Local Interaction





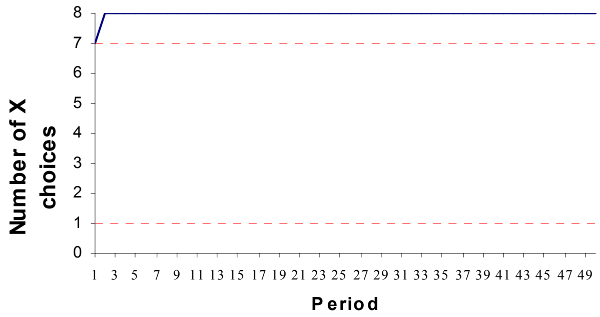




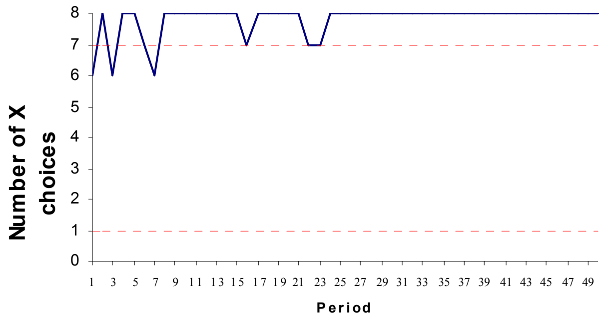
k* = 0.67

Global Interaction

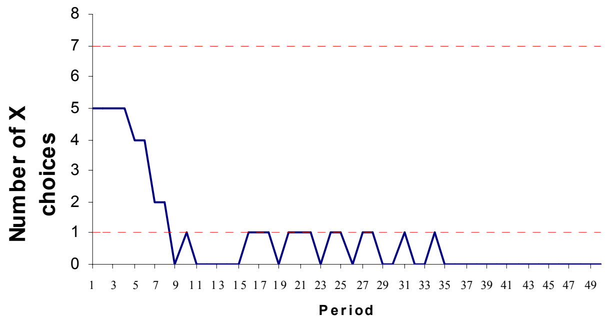
G67.1



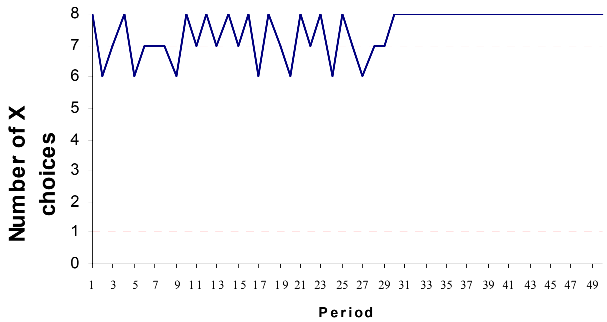
G67.2



G67.3

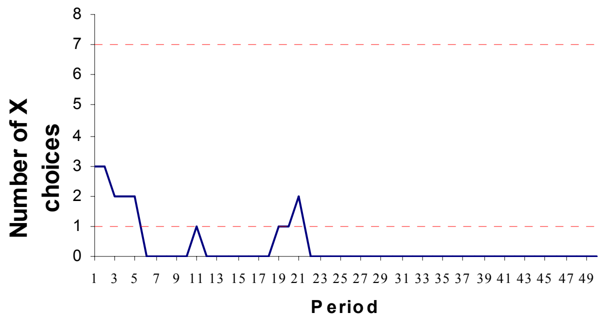


G67.4



Local Interaction

L67.1



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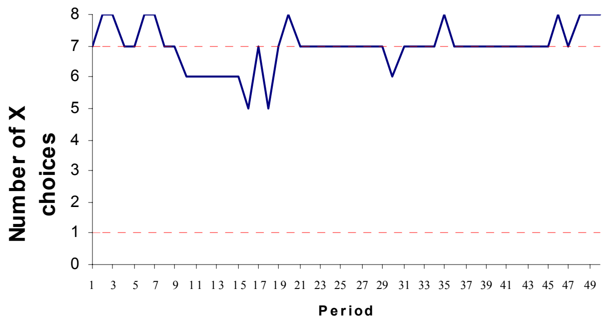

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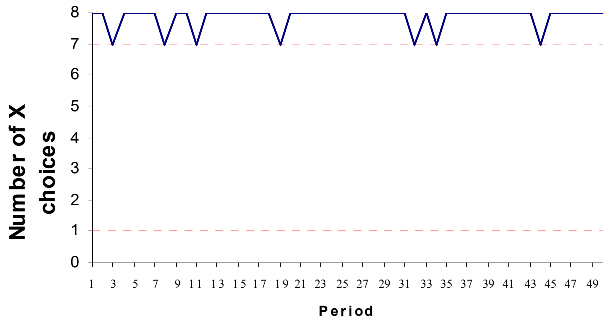
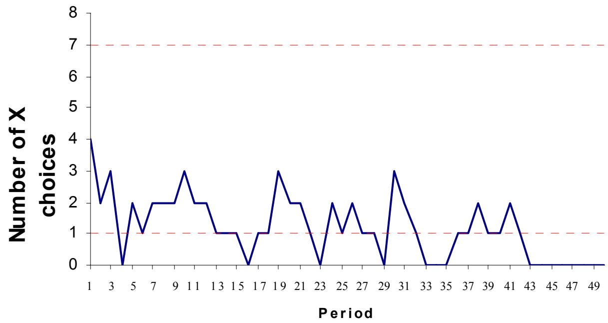
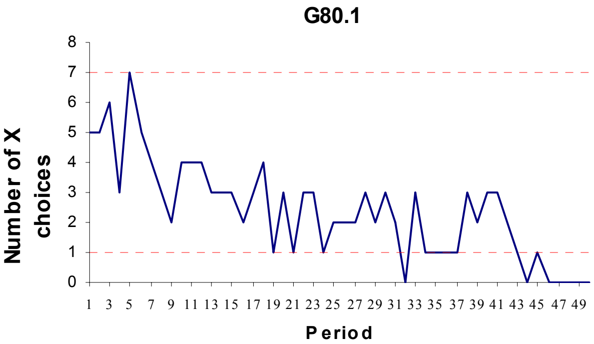


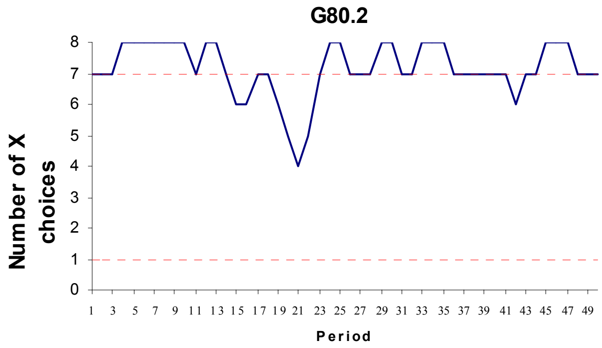
L67.4

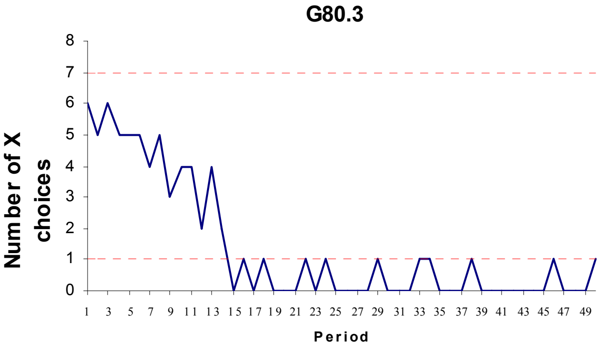


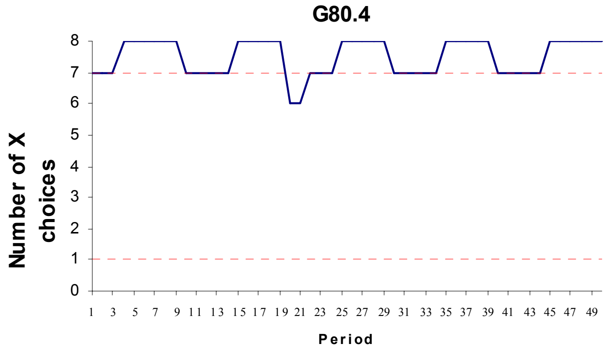
k* = 0.80

Global Interaction

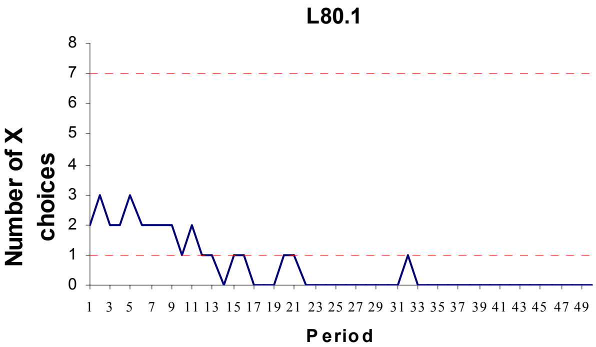


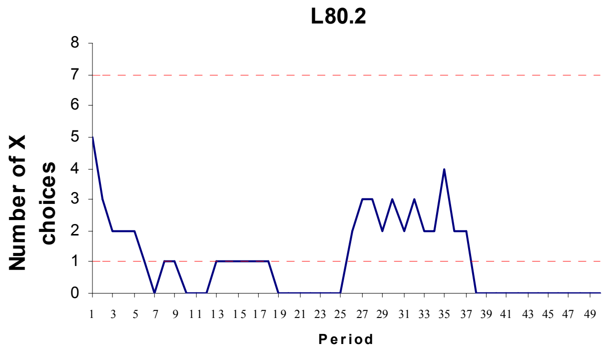


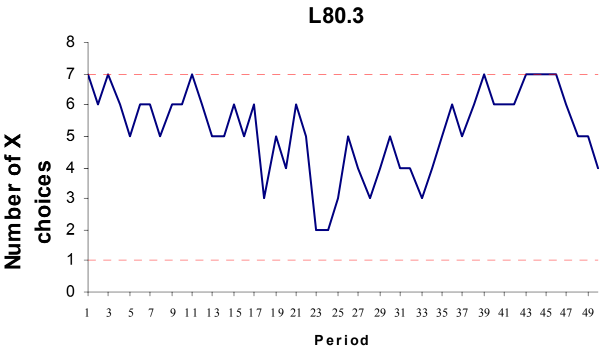


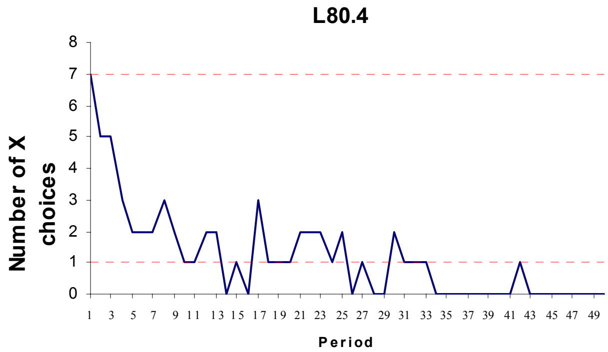


Local Interaction









APPENDIX B

Global Interaction			*Local Interaction*		
Group	Convergence Period	# of periods inside CB	Group	Convergence Period	# of periods inside CB
G54.1	1	50	L54.1	37	42
G54.2	3	49	L54.2	36	39
G54.3	18	49	L54.3	25	45
G54.4	7	48	L54.4	45	48

(a): k* = 0.54.

Global Interaction			*Local Interaction*		
Group	Convergence Period	# of periods inside CB	Group	Convergence Period	# of periods inside CB
G67.1	1	50	L67.1	3	48
G67.2	1	50	L67.2	19	48
G67.3	7	44	L67.3	1	50
G67.4	1	50	L67.4	31	45

(b): k* = 0.67.

Global Interaction			*Local Interaction*		
Group	Convergence Period	# of periods inside CB	Group	Convergence Period	# of periods inside CB
G80.1	42	25	L80.1	6	48
G80.2	23	47	L80.2	36	43
G80.3	14	40	L80.3	-	-
G80.4	1	50	L80.4	18	44

(c): k* = 0.80.

<u>Table 5:</u> Convergence analysis (tolerance bound of 2/8).