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Strategic pattern recognition—experimental evidence

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Abstract

The repeated play of an asymmetric Battle of the Sexes is analyzed from the perspective of "strategic pattern recognition." Convergence to equilibrium patterns (in finite histories) and related concepts like breaking-an-equilibrium-pattern are defined and applied to the data. More than half of 202 pairs of subjects are characterized as weakly converging to a fixed equilibrium pattern. The results also show that subjects tend to break their best pattern in cases where their partners' payoffs are relatively low and that convergence initiation does not pay off. While female subjects frequently reject the males' best equilibrium with anonymous matching, behavior gets more cooperative when pairs are introduced to each other before the beginning of the game.

JEL classification: C72; C92; D83

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1. Introduction

The cognitive psychology literature has long ago demonstrated that people tend to find regularities and detect covariations even when they do not necessarily exist (e.g., Allan and Jenkins, 1980; Arkes and Harness, 1983). Alloy and Tabachnik (1984) suggest that the detection of such regularities helps us understand the past and predict the future. Avrahami and Kareev (1994) demonstrate that subjects tend to associate sequences of stimuli, even if the elements composing each sequence are not naturally correlated. In general, the inclination to "recognize patterns" in sequences of observations seems like a

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natural characteristic of human perception. It is therefore interesting to explore the possible implications of this tendency on dynamic decision-making and strategic interaction. In this paper we analyze the repeated play of a modified Battle of the Sexes from the perspective of *strategic pattern recognition*.

Additional motivation comes from the learning paper of Sonsino (1997). In that paper we study a class of probabilistic learning models where the agents recognize cyclic patterns in the observed play. If for instance the observed history at some stage of the repeated game ends with $\ldots, \mathbf{A}, \mathbf{B}, \mathbf{A}, \mathbf{B}, \mathbf{A}, \mathbf{B}, \mathbf{A}, \mathbf{B}$ where **A** and **B** are two strategy profiles of the stage game, then the agents "recognize" the cyclic pattern $\mathbf{A}, \mathbf{B}$; that is, each player expects his rivals to play (their part in the strategy profile) **A** in the subsequent round of the game and thus plays a best response to **A** (with large probability). If **A** is a pure strategy Nash equilibrium than the observed play will conform to the pattern's prediction. If however **A** is not a pure equilibrium then at least one of the players will deviate from the pattern. The paper shows that probabilistic learning models that satisfy some minimal noise conditions and comply with a set of axioms on strategic pattern recognition converge with probability one to the collection of equilibrium patterns, in a large class of "simple games" where the pure-strategy equilibria are nicely spread along the lattice of the game. When playing *Battle of the Sexes* games for instance (see Fig. 1), the players may converge to the Rows' best equilibrium (B, B); i.e., start playing the profile (B, B) at some stage of the repeated game; or they may converge to Cols' best equilibrium (A, A); i.e., start playing this equilibrium repeatedly at some stage of the repeated interaction. Alternatively, the players may converge to the symmetric pattern $(A, A), (B, B)$; repeatedly alternating between the two equilibrium points. They may also converge to asymmetric patterns like $(A, A), (B, B), (B, B)$ or $(A, A), (A, A), (B, B)$ and even to larger patterns like $(A, A), (A, A), (B, B), (B, B)$ and others. The convergence result says that with probability one the players adopt one of these patterns eventually.

In the current paper we analyze the repeated play of the modified Battle of the Sexes (henceforth: BoS) described in Fig. 1 from the perspective of strategic pattern recognition. In particular, we have asked 202 pairs of subjects (students at the Technion) to play the game repeatedly in fixed pairs of mixed gender for 30–40 rounds in 4 different conditions:

(1) anonymous matching with male at the rows-player role;
(2) anonymous matching with female at the rows-player role;
(3) personal matching with male at the rows-player role;
(4) personal matching with female at the rows-player role.

The social-distance and gender manipulations were ad-hoc selected to add some dimensions of interest.

We find that more than 50% of the subjects satisfy our criterion for "weak convergence to an equilibrium pattern." Most of these subjects repeatedly alternate between equilibrium (A, A) and equilibrium (B, B). Many subjects however converge to one of the two equilibria or even to longer patterns like $(A, A), (A, A), (B, B), (B, B)$.

Here are some of the other main findings:

(1) Subjects exhibit care for their partner in the (strong) form of breaking their best-equilibrium patterns when their partner's payoffs are relatively low.
(2) Convergence initiation does not pay off: the payoffs obtained by subjects that initiate convergence are significantly lower than those obtained by other subjects that converge.
(3) The composition of adopted-patterns strongly depends on the realized play at the first round of the game.
(4) The performance of subjects in pairs that do not converge deteriorates with time.
(5) In the anonymous treatments, the convergence rate to the females' best equilibrium is three times larger than the convergence rate to the males' best equilibrium. This surprising gender effect disappears with personal matching (where the convergence rates are similar).

The fact that subjects may quickly learn to alternate when playing games with multiple efficient equilibria was already documented in the pioneering experiments of Rapoport et al. (1976).[1] Prisbrey (1994) compares subjects' behavior when playing symmetric and asymmetric 2×2 games and claims that the ability of players to obtain efficient outcomes by way of alternation is diminished when there are large asymmetries in the game. Bhaskar (2000) proves that the efficient symmetric equilibria of finitely repeated BoS games must be egalitarian; i.e., equalize as far as possible the realized payoffs of the two players. Lipman and Wang (2000) however show that when there are costs for switching strategies and the BoS is repeated "frequently enough" within each period of time then the players must repeatedly play the same pure strategy equilibrium (in every subgame perfect equilibrium of the extended game).

In the current paper we examine the distribution of equilibrium patterns adopted by the subjects in the 4 different treatments. We also study other aspects of strategic pattern recognition that were not examined (to the best of our knowledge) in the existing literature; e.g., subjects inclination to deviate (or break) equilibrium patterns; their attempts to initiate convergence to equilibrium patterns and more.

The paper proceeds as follows: Section 2 describes the experiment. Section 3 introduces the formal definitions that are used in analyzing the data. Section 4 describes the general results; Section 5 deals with the social-distance effects and Section 6 with the gender effects. Section 7 is a concluding discussion.

2. Method

The experiment took place in the computerized laboratory at the Faculty of Industrial Engineering and Management at the Technion. More than 400 students from all departments at the Technion were recruited by posting advertisements calling students to register (by phone) to a money-paying experiment in decision making. In the experiment, subjects were asked to play repeatedly, for 30–39 rounds, in fixed pairs, the BoS game described in Fig. 1.

[1] See also Ochs (1995) for a survey of other experimental works on the BoS and different coordination games.

	Col *A*	Col *B*
Row *A*	95, 168	30, 30
Row *B*	30, 30	198, 99

Fig. 1. Modified battle of the sexes.

The game has two players: *Rows* picks the row; *Cols* picks the column. As in the standard BoS, there exist two pure strategy Nash equilibria (A, A) and (B, B) where (A, A) pays the larger payoff (168) to Cols and (B, B) pays the largest payoff (198) to Rows. If the players fail to coordinate, each of them receives a smaller symmetric disagreement payoff (30). The modification on the standard BoS is in the asymmetry introduced to the equilibrium payoffs. Since the sum of equilibrium payoffs of Rows $(95 + 198)$ is higher than the sum of equilibrium payoffs of Cols $(168 + 99)$, we sometimes call Rows role *superior* compared to the *inferior* role of Cols. Since equilibrium (B, B), pays 99 or 198, while equilibrium (A, A) correspondingly pays 95 or 168, we sometimes term (B, B) the *relatively-efficient* equilibrium (although Pareto-dominance does not apply). Strategy B is sometimes referred to as the *favorite strategy of Rows*. Similarly, A is sometimes called the *favorite strategy of Cols*.

Table 2 describes the four treatments implemented and the number of pairs in each treatment. In the anonymous treatments (**A**), 10–14 subjects were randomly assigned to the 14 computers in the laboratory and told that they would play the game repeatedly with an anonymous fixed partner of the opposite gender from the current pool in the lab. In the personal treatments (**P**), subjects in each pair were introduced to each other and asked to chat for five minutes in order to get acquainted before the experiment begins. All pair assignments were of mixed gender. In the Row-Player-Male (**RPM**) treatments, the superior rows-player role was assigned to a male and the inferior Cols role to a female. In the Row-Player-Female (**RPF**) treatments, Rows was female and Cols, male.[2]

At the beginning of the experiment (after the introductory chatting stage in the personal treatments), subjects were asked to login to the system, fill in some personal details and read the instructions online (see Appendix A for the translated version).[3] In each round, subjects observed the payoff matrix of the game with their own strategies and payoffs illuminated and asked to click their selected strategy. The experiment screen also presented the private history of the repeated game; i.e., a chronicle list of the choices made by

Table 2
Treatments

Treatment	Matching-type	**R**ows **P**layer	Number of pairs
A/RPM	**A**nonymous	**M**ale	54
A/RPF	**A**nonymous	**F**emale	49
P/RPM	**P**ersonal	**M**ale	46
P/RPF	**P**ersonal	**F**emale	53

2 In the general discussions however we use the female pronoun for the Rows and the male pronoun for Cols.
3 The experiment was programmed in Visual Basic 6 on NT4 Windows 98 environment.

each player in the previous rounds. In addition, subjects observed (in both anonymous and personal designs) the personal details (including gender and age) supplied by their opponent and the average payoff earned by each player up to the current round. At the end of each round, a feedback window specifying the choices made and payoffs earned by the two players appeared. Subjects were asked to click a “continue to next round” button to proceed. No time limits were imposed in any stage of the experiment. The actual number of rounds (between 30 and 39) was randomly determined for each pair and was not disclosed to the subjects in advance.

At the end of the session, each subject received $1/4$ of his average payoff along the game. The average payoff per subject was 26.8 NIS (approximately 6.5 US dollars). Each session lasted about 30–45 minutes. We ran 8 sessions in each treatment with a total of 202 pairs of subjects all together (see Table 2).

3. Definitions

Consider first the stage game as described in Fig. 1. We use bold **A** to denote the equilibrium (A, A) and bold **B** to denote (B, B). We say that p is an *equilibrium pattern* of the game if p is a finite sequence of pure-strategy Nash equilibria. In our special case, each equilibrium pattern is a sequence of **A**'s and **B**'s; **A**, **B**, for example, denotes the symmetric pattern, equilibrium **A** followed by equilibrium **B**. We use $\ell(p)$ to denote the length (i.e., the number of elements) in pattern p. We say that p is a singleton pattern iff $\ell(p) = 1$.

Let $z = s_1, s_2, \ldots, s_n$ denote the realized history of play for some arbitrary pair of subjects. Following the notation in Sonsino (1997) we use the projection function PRO to denote subsequences of z; i.e., for every two indexes t_1 and $t_1 + k$ such that $1 \leqslant t_1 \leqslant t_1 + k \leqslant n$, $\mathrm{PRO}_{t_1, t_1+k}(z) = s_{t_1}, s_{t_1+1}, \ldots, s_{t_1+k}$.[4] Similarly, we use the extension function EXT to denote extensions of given patterns; i.e., for every pattern p and integer $t' > \ell(p)$,

$$\mathrm{EXT}_{1,t'}(p) = \overbrace{p,\ p,\ \ldots,\ p,}^{t' \text{ div } \ell(p) \text{ repetitions of } p} \quad s_1, \ldots, s_{t' \bmod \ell(p)}.$$

For instance, $\mathrm{EXT}_{1,5}(\mathbf{A}, \mathbf{B}) = \mathbf{A}, \mathbf{B}, \mathbf{A}, \mathbf{B}, \mathbf{A}$.

As in the preceding paper we would not wish to treat cyclic sequences like **A**, **B**, **A**, **B**, **A**, **B** as equilibrium patterns of the game. We thus define the collection of *basic equilibrium patterns* recursively as follows:

SP_1 is the collection of singleton equilibrium patterns; i.e., $\mathrm{SP}_1 = \{\mathbf{A}, \mathbf{B}\}$
$\mathrm{SP}_n = \{s_1, \ldots, s_n \mid s_i \in \{\mathbf{A}, \mathbf{B}\} \text{ for } i = 1, \ldots, n\} \setminus \bigcup_{\{j \mid n \bmod j = 0\}} \mathrm{EXT}_{1,n}(\mathrm{SP}_j)\}$, for $n = 2, 3, \ldots$.

The sequence **A**, **B**, **A**, **B**, **A**, **B** then represents 3 successive repetitions of the basic pattern **A**, **B**.

With these preliminaries we can now present the formal conditions that are used to characterize subjects' behavior in the sample.

[4] When $k = 0$, $\mathrm{PRO}_{t_1}(z) = s_{t_1}$.

3.1. Convergence to equilibrium patterns

First we define a notion of strong convergence to an equilibrium pattern. Clearly, any such definition must be arbitrary since one cannot refer to eventual events when dealing with finite histories.[5] We choose to say that the subjects have strongly converged to an equilibrium pattern p iff

(1) the pattern was played several times (at least 4 times for singleton patterns; at least three times for longer patterns) successively at the end of the observed history; and
(2) nowhere before in the observed history an equilibrium pattern was played for that long and then disrupted.

In particular, when the observed history ends with 4 successive repetitions of the equilibrium (A, A) our definition may imply strong convergence to **A** if

(1) this is the only case where the players played a single equilibrium strategy for 4 successive rounds;
(2) no equilibrium pattern of length $\geqslant 2$ was played twice successively and then disrupted.

If however equilibrium **B** was played for 4 successive rounds before the ending string of 4 successive **A**'s, then the history is not classified as a case of convergence to **A** (since **B** was previously played for "that long" and then disrupted). Strong convergence to longer equilibrium patterns like **A**, **B** or **A**, **A**, **B**, **B** is similarly defined. For instance, a history ending with **A**, **B**, **A**, **B**, **A**, **B** may be classified as a case of strong convergence to **A**, **B**. However, the definition will not apply if the sequence **A**, **B**, **B**, **A**, **B**, **B** has previously appeared along the repeated game.

Definition (pattern covering history). We say that pattern p covers the last $N \geqslant \ell(p)$ periods of history $z = s_1, s_2, \ldots, s_n$ iff $\mathrm{PRO}_{n-N+1,n}(z) = \mathrm{EXT}_{1,N}(p)$.

Definition (strong convergence to equilibrium pattern). Let $z = s_1, s_2, \ldots, s_n$ present a history of the game. We say that the subjects strongly converged to the equilibrium pattern p (at round $n - N + 1$; in z) iff the following two conditions hold:

(1) The pattern p covers the last N periods of z for some $N \geqslant \max\{4, 3 \cdot \ell(p)\}$.
(2) For every $m < n$, no equilibrium pattern $\tilde{p}$, covers the last $M = \max\{N, 2 \cdot \ell(\tilde{p})\}$ periods of the history $s_1, s_2, \ldots, s_m$.[6]

[5] The computer sciences literature (see, for example, (Laird, 1994) and (Laird and Saul, 1994)) deals with similar issues when developing algorithms for identifying patterns in sequential data.

[6] The definition may produce counter intuitive classifications in certain cases; for instance, histories that end with a sequence of 4 successive **A**'s, followed by 5 successive **B**'s, followed by 6 successive **A**'s may fit the definition of strong convergence to **A**. No such cases were observed in our sample. See also the brief discussion of alternative definitions in Section 7.

Note that since the adopted pattern must appear at least three times successively at the end of the observed history, strong convergence can only apply to one basic equilibrium pattern at a time.[7] From condition (2) in the definition it follows that the round of strong convergence is also uniquely defined.

The convergence definition introduced above is strong in the sense that it does not allow for any mistakes or deviations. In practice, many subjects seemed to have adopted a fixed equilibrium pattern at some stage of the repeated game but occasionally deviated from that pattern so that the formal conditions suggested above did not apply. To characterize these cases we define a weaker notion of weak convergence as follows: A pair of subjects is said to have weakly converged to pattern p when by deleting up to 20% of the recent elements in the history z we get a subsequence that satisfies the conditions for strong convergence. A formal definition follows:

Definition (necessary conditions for weak convergence). Let $z = s_1, s_2, \ldots, s_n$ present a history of the game. We say that the necessary conditions for weak convergence to the equilibrium pattern p hold (in z) when the following two conditions are satisfied:

(1) there exists a subsequence of indices $1 \leqslant i_1 < i_2 < \cdots < i_m \leqslant n$ such that the conditions for strong convergence to pattern p at round i_1 hold in the subsequence

$$s_1,\ s_2,\ \ldots,\ s_{i_1-1},\ s_{i_1},\ s_{i_2},\ \ldots,\ s_{i_m};$$

(2) $m/(n - i_1 + 1) > 0.8$.

Note that the necessary conditions may concurrently hold for several basic equilibrium patterns. For instance, take some history ending with $\ldots$, **A**, **B**, **B**, **B**, **B**, **A**, **B**, **B**, **B**, **B** so that the conditions for strong convergence to **A**, **B**, **B**, **B**, **B** hold. Clearly, the necessary conditions for weak convergence to that pattern are also satisfied. Moreover, the necessary conditions for weak convergence to **B** may hold in this history as well (simply omit the **A** between the two sequences of **B**'s). The necessary conditions however were never simultaneously realized for two different basic patterns in our sample.[8] We thus say that a pair of subjects has weakly converged to pattern p whenever the necessary conditions for weak convergence to p hold.

The conditions stated above however may still concurrently hold for several different sequences of indices; say, $i_1^1 < i_2^1 < \cdots < i_{m_1}^1$; $i_1^2 < i_2^2 < \cdots < i_{m_2}^2 < \cdots$; $i_1^k < i_2^k < \cdots < i_{m_k}^k$. We say that the subjects have *weakly converged to pattern p at round t* iff t is the minimal index for which the definition of weak convergence applies; i.e., $t = \min\{i_1^1, i_1^2, \ldots, i_1^k\}$. The date of weak convergence might thus be strictly lower than

[7] See the argument in Sonsino (1997, p. 303).

[8] The necessary conditions frequently held for different "shifts" of the same pattern; e.g., for the patterns **A**, **B** and **B**, **A** concurrently. In classifying cases of strong and weak convergence however we do not distinguish between different shifts of the same pattern (see the discussion at the end of this section). The costs of presenting necessary and sufficient conditions for weak convergence to a unique (say, up to the shift transformation) equilibrium pattern seem unworthy since no multiplicity was observed.

the date of strong convergence; e.g., when the observed history of the game ends with $\ldots, \mathbf{A}, \mathbf{A}, \mathbf{A}, \mathbf{B}, \mathbf{A}, \mathbf{A}, \mathbf{A}, \mathbf{A}$.

3.2. Playing long equilibrium patterns

Several pairs in the sample repeatedly played long sequences of **A**'s and **B**'s without meeting the necessary conditions for weak convergence.[9] To characterize the behavior of these subjects we define the notion of playing long equilibrium patterns, LEP. Basically, a pair is said to play LEP if the following 3 conditions are met:

(1) the conditions for weak convergence did not realize;
(2) the pair has played at least 3 long sequences of either equilibrium **A** or equilibrium **B** (where a long sequence should contain at least 3 repetitions);
(3) the equilibrium profiles cover at least 80% of the relevant history.

The formal definition that follows uses the indicator function $1_{s_t \in \{\mathbf{A},\mathbf{B}\}}$ to denote the case where the realized play at round t was either **A** or **B**:

Definition (playing long equilibrium patterns). Let $z = s_1, s_2, \ldots, s_n$ present a history of the game that does not satisfy the necessary conditions for weak convergence. We say that the subjects played Long Equilibrium Patterns (LEP) in z iff there exists a sequence of indices $1 \leqslant i_1 < j_1 < i_2 < j_2 < i_3 < j_3 \leqslant n$ with $j_k \geqslant i_k + 2$ for $k = 1, 2, 3$ such that

(1) For every $k = 1, 2, 3$ one of the following conditions hold:

$$\mathrm{PRO}_t(z) = \mathbf{A} \quad \text{for every } t = i_k, i_k + 1, \ldots, j_k, \tag{1.1}$$

or

$$\mathrm{PRO}_t(z) = \mathbf{B} \quad \text{for every } t = i_k, i_k + 1, \ldots, j_k \tag{1.2}$$

and each of the equalities (1.1) and (1.2) holds for some $k \in \{1, 2, 3\}$.

(2) $$\frac{\sum_{t=i_1}^{n} 1_{s_t \in \{\mathbf{A},\mathbf{B}\}}}{n - i_1 + 1} \geqslant 0.8.$$

3.3. Breaking and initiating patterns

In this section we use p^i, $\mathrm{PRO}^i(z)$, $\mathrm{EXT}^i(p)$ to denote player i's role in the corresponding sequences. For instance, if p is the symmetric pattern **A**, **B** then p^i is the sequence of strategies A, B and $\mathrm{EXT}^i_{1,5}(p) = A, B, A, B, A$ (for each player i). We say that pattern p was broken by player i if both subjects played the pattern repeatedly for several rounds (at least 3 times for singleton patterns; at least twice for longer patterns) but then i disrupted the pattern by deviating from its prescription. The definition should also apply to

[9] For example, take the case (pair 2; session 12) where the observed history ended with 5 successive **A**'s; followed by 2 rounds of non-equilibrium play; followed by 15 successive **B**'s; followed by (A, B); followed by 10 successive **A**'s.

cases where both players break an equilibrium pattern simultaneously; e.g., to cases where the subjects follow **A** for several rounds and unexpectedly switch to **B**. Such a general definition however would suggest that both players break the pattern **A** repeatedly when playing a sequence like **A**, **A**, **A**, **B**, **B**, **B**, **A**, **A**, **A**, **B**, **B**, **B**. Intuitively, we would not wish to count the second shift from **A** to **B** as a case where subjects break the singleton pattern **A** since the subjects are following the longer pattern **A**, **A**, **A**, **B**, **B**, **B** at that stage. We thus restrict the definition to cases where the agents do not play such a larger equilibrium pattern successively (see condition (3) in the definition that follows).

Definition (breaking equilibrium pattern).[10] Let $z = s_1, s_2, \ldots, s_n$ present a history of the game. We say that subject i broke the pattern p at date $t \leqslant n$ (in z) iff the following conditions hold:

(1) the pattern p covers the last $N \geqslant \max\{3, 2 \cdot \ell(p)\}$ of the sequence $s_1, s_2, \ldots, s_{t-1}$;
(2) $\mathrm{PRO}^i_{t-N,t}(z) \neq \mathrm{EXT}^i_{1,N+1}(p)$;
(3) for every $t' \leqslant t - 2N - 1$,

$$\text{if} \quad s_j \in \{\mathbf{A}, \mathbf{B}\} \quad \text{for every } j = t', t'+1, \ldots, t,$$
$$\text{then} \quad \mathrm{PRO}_{t',t'+N}(z) \neq \mathrm{PRO}_{t-N,t}(z).$$

Next, consider the case where some player i played his role in a given equilibrium pattern p several times (at least three times for singleton patterns; at least twice for longer patterns) “just before” weak convergence to that pattern. In such a case we say that i has initiated convergence to p. A formal definition follows.

Definition (initiating convergence to equilibrium pattern). Let $z = s_1, s_2, \ldots, s_n$ present a history of the game such that the subjects have weakly converged to the equilibrium pattern p at date t in z. We say that subject i initiated convergence to p (in z) iff there exists $m \geqslant \max\{3/\ell(p), 2\}$ and a subsequence of indices $j_1 < j_2 < \cdots < j_m < t - \ell(p) + 1$ such that

(1) $j_{k+1} - j_k \geqslant \ell(p)$ for every $k = 1, 2, \ldots, m - 1$,
(2) $\mathrm{PRO}^i_{j_k, j_k+\ell(p)-1}(z) = p^i$ for every $k = 1, 2, \ldots, m$,
(3) $m \cdot \ell(p)/(t - j_1) \geqslant 0.9$.[11]

For convenience, we henceforth omit the comas when describing a basic equilibrium pattern. The string **AB**, for instance, is used to denote the basic pattern **A**, **B**. We also adopt

[10] Note that deviations from an equilibrium pattern after the date of weak convergence are counted as cases where the corresponding pattern was broken.

[11] The definition may accommodate special cases where both players initiate convergence to a given pattern (e.g., when the players play (A, B) for 30 rounds; (B, A) for 3 rounds and then converge to equilibrium **A**). No such cases were observed in the sample.

one "canonical" form to describe different shifts of the same basic pattern.[12] The string **AABB** for instance is used to denote the patterns **AABB**, **ABBA**, **BBAA**, and **BAAB**. We say that the subjects have weakly converged to **AABB** if the necessary conditions for weak convergence hold for one of these 4 versions.

4. Results, general

4.0. Note on statistical method

A preliminary note on the statistical method. We use non parametric tests for most of the comparisons: (Wilcoxon) Mann–Whitney tests are used to compare behavior across subsamples while Wilcoxon signed-rank tests are used for paired samples (Snedecor and Cochran, 1989). The Kolmogorov–Smirnov test is used to test the hypothesis that two independent samples come from the same distribution (Siegel and Castellan, 1988). The standard Z-test (Snedecor and Cochran, 1989) is used to compare binomial proportions across subsamples. In all cases we report the one-tail significance levels unless the insignificance is apparent. Since p was reserved for denoting strategic patters, we use α to denote significance levels; n.s. (for "not significant") is used whenever $\alpha > 0.1$.

4.1. Convergence

Approximately half of the pairs in the sample have adopted a fixed equilibrium pattern at some stage of the repeated game. The strong convergence rate was 47% (95 pairs from a sample of 202). The weak convergence rate was 58% (117 pairs). In addition, 5% of the subjects (11 pairs) have played several long strings of **A**'s or **B**'s and met the LEP criterion. The average strong-convergence round was 12.25; the average weak-convergence round was 8.95.

The first line on Table 3 gives the distribution of patterns adopted by the pairs that have weakly converged. Almost sixty percent of these pairs (67 from 117) have adopted the symmetric pattern **AB**. The convergence rate to equilibrium **A** (19.66%; 23 pairs) was higher than the convergence rate to **B** (12.82%; 15 pairs).[13] A Wilcoxon signed-rank

Table 3
Adopted and broken patterns (%)

	A	**B**	**AB**	**AABB**	**AAABBB**
Weak convergence	19.66	12.82	57.26	5.98	4.27
Strong convergence	21.05	11.58	58.95	7.37	1.05
Broken by Rows	55.81	20.93	20.93	2.33	0
Broken by Cols	19.42	57.28	22.33	0.97	0

[12] The pattern $\hat{s}_1, \hat{s}_2, \ldots, \hat{s}_n$ is a (m-periods: $m \in \{1, 2, \ldots, n-1\}$) shift of the pattern $s_1, s_2, \ldots, s_n$ iff $\hat{s}_1, \ldots, \hat{s}_n = s_{m+1}, \ldots, s_1, \ldots, s_m$.

[13] The high convergence rates to **A** were mostly observed in the ARPM treatment, see the detailed discussion in Section 6.

test however suggests that the differences in session-level convergence rates to the two singleton patterns were not statistically significant ($N = 22$; $Z = 0.6$; n.s.).[14]

Seven pairs in the pool have converged to the symmetric pattern **AABB** while five pairs have adopted **AAABBB**. None of the pairs has converged to asymmetric patterns like **ABB** or **AAB**. In several cases one of the players has repeatedly followed some asymmetric pattern but the other player refused to adopt the asymmetric solution. All together, we had 79 (of 117) pairs weakly converging to symmetric "reciprocal" patterns.[15] The distribution of patterns adopted by pairs that have strongly-converged was similar to the distribution for weakly converging pairs (see line 2 on the table).

4.2. Individual performance

The average payoff of subjects assigned to Rows role was 110.41; the corresponding number for subjects in the Cols role was 104.5. Note that the efficient payoff to Cols when Rows earns 110.41 is 157.68, about 50% more than the actual payoff of Cols in the game. Similarly, the efficient payoff to Rows when Cols earns 104.5 is 189.78; about 70% higher than the actual payoff in the experiment. Thus, on average, players in both roles ended the experiment deep inside the convex hull of stage-game payoffs. The increased conflict induced by the asymmetry of the game may have contributed to the low levels of efficiency (see (Prisbrey, 1994) for direct evidence on the negative effect of payoff asymmetries on achieved levels of efficiency).

Further examinations show that equilibrium (A, A) was played in 37.4% of the rounds (2592 rounds from 6931) while equilibrium (B, B) was played in 33.4% of the cases. The small difference between the average payoffs of Rows and Cols thus follows from the large proportion of unsuccessful coordination and from the fact that the two equilibria were played in similar frequencies along the games.

4.3. Initiating and breaking equilibrium patterns

In 43 cases (out of 117 cases of weak convergence) the convergence was initiated by one of the players. Rows has initiated convergence in 23 cases while Cols initiated convergence in 20 cases. Interestingly, Rows has initiated convergence to **AB** in $11/23$ cases while Cols has initiated convergence to **A** in $15/20$ cases.[16] The relatively high initiation rate of **A** by Cols seems surprising. In Section 6 we show that subjects assigned to Cols role tend to play long strings of their favorite strategy A (mostly, in the ARPM treatment). A possible explanation is that Cols' inferior position in the game generates a resentment to the other-

14 The convergence rates to the two patterns were equal in 10 sessions.

15 See Fehr and Gächter (2000) for a general discussion of the role of reciprocity in establishing and enforcing social-norms.

16 In addition, Rows has initiated convergence to **A** in 4 cases, to **B** in 5 cases and to **AABB** in 3 cases. Cols has initiated convergence to **B** is 2 cases, to **AB** in 2 cases and to **AABB** in 1 case.

player's nicer equilibrium (B, B) together with an increased inclination to play his favorite strategy A.[17] This may also explain the high initiation rate of **A** by col-players.

A comparison of the payoffs earned by players that have initiated convergence to the payoffs earned by players that have weakly converged without initiating convergence suggests that convergence initiation did not payoff. The median average payoff of row-players that have initiated convergence was 122.3 compared to a median average payoff of 135.2 for the other row-players that have (weakly) converged. The corresponding numbers for col-players are: 102.2 (median average payoff of col-players that have initiated convergence) and 124.9 (median average payoff of other col-players that have converged). Mann–Whitney tests (pair-level) suggest that both differences are one-tail significant at $\alpha < 0.05$.[18]

Convergence of behavior was not always smooth as subjects broke many equilibrium patterns along the repeated games. The symmetric pattern **AB** was broken 50 times; **AABB** was violated 4 times. The singleton patterns (**A** and **B**) were broken 189 times along the games. Naturally, Rows was more inclined to deviate from equilibrium **A** while Cols tended to break **B**. In particular, Rows broke **A** 76 times and **B** 30 times while Cols broke **A** 22 times and **B** 61 times. Note that subjects in both roles frequently broke their favorite singleton patterns. This can be explained in two ways:

(1) subjects break their best pattern because of strategic considerations (Rows for instance plays A after a sequence of 3 **B**'s since she expects Cols to insist on A after "yielding" to **B** for 3 successive rounds), or
(2) subjects care about their partner's payoffs.

Further examinations show that the average payoffs of Cols in those pairs where Rows broke **B** (median 100.86) were significantly lower than the average payoffs of col-players in those pairs where Rows did not break **B** (median 106.26) (Mann–Whitney test; $N = 202$; $Z = 2.2739$; $\alpha = 0.0115$). The average payoffs of Rows herself were not significantly different across the two samples (medians: 107.26 and 110.11 correspondingly). Similarly, the average payoffs of Rows in those pairs where Cols broke **A** (median 95.5) were significantly lower than the payoffs of Rows in those pairs where Cols did not break **A** (median 110.98) (Mann–Whitney test; $N = 202$; $Z = 1.3634$; $\alpha = 0.086$). Again, the corresponding payoffs of Cols were not significantly different across the two samples ($Z = 0.6082$; n.s.).

To conclude, subjects in both roles tended to break their favorite equilibrium patterns in cases where the average payoffs of their partners were relatively low. The "breaking your favorite equilibrium" type of behavior thus seems to follow from social-preferences considerations as suggested in (2) above. Charness and Rabin (2001) indeed demonstrate

[17] Resentment to conceived-unfair payoff distributions has been documented in numerous experimental studies; for a recent example see the ultimatum-game newspaper experiment of Güth et al. (2002). See also (Elster, 1998) and (Loewenstein, 2000) for general surveys on emotions and economic behavior.

[18] The Mann–Whitney statistics ($N = 117$) are 1.6871 for the first comparison and 2.4109 for the second.

(in different type of experiments) that *relatively* well-off subjects put larger weight on their partner's payoffs and are more inclined to "helpful-sacrifice" type of behavior.[19]

4.4. First-round play and later performance

Equilibrium (A, A) was observed more frequently than (B, B) in the first round of the experiment. In particular, 67 pairs (33%) started with (A, A) while only 35 pairs (17%) opened with (B, B).[20] A plausible explanation is that subjects are naturally inclined to prefer "A" on "B" when there are no other "historic" reasons to discriminate between the two. In other words, the alphabetic ordering makes (A, A) the focal equilibrium (Kreps, 1990) at the first round of the game.[21]

The convergence rates of subjects that have started the experiment playing an equilibrium (49% strong-convergence rate; 60% weak-convergence rate) were slightly higher than the convergence rates of those that did not coordinate at the first round (45% and 56%, respectively). The average payoffs earned by subjects in the first group were significantly higher than the average payoffs obtained by the subjects in the second group: the median average payoffs were (115.9, 115.2) for subjects that have started with an equilibrium vs. (104.9, 93) for subjects that did not.[22]

The numbers on Table 4 reveal some significant differences in the performance of pairs that have started with (B, B) compared to the performance of those that have started with (A, A). The weak-convergence rate (WCR) of the subjects that have started with (B, B) was 69% compared to 55% for those starting with (A, A). The corresponding strong-convergence rates (SCR) were 54% and 46%. The conditional convergence rates to the patterns **A**, **B**, and **AB** (in each subsample) are also disclosed on the table. Interestingly, we observe that the composition of patterns adopted strongly depends on the realized first-round play. In particular, pairs that have started with (B, B) have converged to the singleton pattern **A** in 4 cases while none of the 37 pairs that have opened with (A, A) has adopted **B**.

The average payoffs earned by players that started the repeated game with their favorite equilibrium were significantly higher than the payoffs earned by players that started with

Table 4
First round play and performance

First round	SCR (%)	WCR (%)	**A**	**B**	**AB**	RPP	CPP
(B, B)	54	69	4/24	4/24	14/24	117.38	103.2
(A, A)	46	55	8/37	0/37	26/37	113.14	116.25
No coordination	45	56	11/56	11/56	27/56	104.9	93

[19] Charness and Rabin (2001) analyze subjects' behavior in one-shot play of various simple dynamic games.

[20] A Wilcoxon signed-rank test suggests the session-level frequencies of starting with **A** were significantly higher than the corresponding frequencies for **B** ($N = 25$; $Z = 2.9866$; $\alpha = 0.0014$).

[21] Because of sample-size limitations, we did not run the transposed version of the game where the relatively efficient equilibrium is also the focal one. We conjecture that this manipulation would not have significantly affect the main results.

[22] Mann–Whitney statistics: $Z = 3.06$; $\alpha < 0.01$ for row-players; $Z = 4.37$; $\alpha < 0.001$ for col-players.

their partner's best equilibrium. The median average payoffs for each player in each category are presented in the columns RPP (for row-player payoff) and CPP (for col-player payoff) in Table 4.

4.5. Dynamics

Table 5 gives some statistics on subjects' behavior in each 10-periods block of the experiment.[23] The first line gives the number of pairs that have weakly converged in each block. The numbers reveal a sharp decrease in convergence-rates with time. While 76 pairs adopt a fixed pattern in the first block of the experiment, only 18 pairs converge in the last 2 blocks. Lines 2–4 give the composition of play in each block. Again, the numbers demonstrate that the improvement in coordination levels marginally decrease with time. While the proportion of unsuccessful coordination, for example, has decreased in 9% (from 39% to 30%) across the first two blocks, the proportion has only decreased in 4% (from 23% to 19%) in the last two blocks. Lines 5–6 on the table demonstrate that players' inclination to play their favorite strategies (B for Rows, A for Cols) did not change significantly along the experiment. The increased level of coordination however has significantly improved the average payoffs earned at the first three blocks (Wilcoxon signed-rank tests; $\alpha < 0.001$ for all comparisons). The average payoffs obtained in block 4 were not significantly different from those obtained in block 3. (See the two lines at the bottom of Table 5 for the median average payoff in each block). To conclude, these results may suggest that the length chosen for the repeated games was sufficient in the sense that a longer horizon would not have affected the results a lot.

The improvement in performance of subjects that have weakly converged or played LEP was in fact partially offset by a decrease in coordination levels of the 74 pairs that did not converge nor played LEP. The proportion with which these pairs played the equilibrium strategies (A, A) and (B, B) (see line 1 on Table 6) has decreased from 55% at the second block of the experiment to 52% at the last block (Wilcoxon signed-rank test; $N = 74$; $Z = 1.5139$; $\alpha = 0.065$). The propensity with which individual subjects in these pairs played their favorite strategies has constantly increased along the 4 blocks (see lines 2–3 on the table). At the last block, for instance, row-players in this category played their favorite

Table 5
Per-block statistics

	Block 1	Block 2	Block 3	Block 4
Pairs converging weakly	76	23	15	3
Prop of (A, A)	32%	37%	41%	43%
Prop of (B, B)	29%	33%	36%	38%
Unsuccessful coordination	39%	30%	23%	19%
Rows playing B	54%	55%	53%	53%
Cols playing A	57%	57%	58%	58%
Median Rows payoff	93.4	105.05	123.2	127.42
Median Cols payoff	92.1	99	112.8	122

[23] As mentioned above the length of the 4th block varied across pairs. On average, it had only 4.34 rounds.

Table 6
Per-block statistics for 74 pairs

	Block 1	Block 2	Block 3	Block 4
Prop equilibrium play	48%	55%	54%	52%
Rows playing B	56%	57%	60%	62%
Cols playing A	59%	62%	64%	65%
Rows payoff	80.4	87.7	91.5	72.9
Cols payoff	78.3	88.6	85.2	83.5

strategy B in 62% of the rounds compared to 56% of the rounds in block 1 (Wilcoxon signed-rank test; $Z = 1.715$; $\alpha = 0.043$). The payoffs earned by the subjects in this group have accordingly decreased towards the end of the repeated game (see lines 4–5 on the table for the median average payoffs in each block).

5. Social-distance effects

Recent experimental studies suggest that apparently-minor changes in social-distance conditions might strongly affect subjects' inclination for other-regarding behavior (Bohnet and Frey, 1999). A comparison of the current results for the anonymous (103 pairs) and the personal (99 pairs) treatments also reveals significant differences in convergence rates and individual cooperative inclinations.

As intuitively expected, the convergence rates are significantly higher with personal matching (see the top line on Table 7). This translates into significantly higher average payoffs for both players (see lines 5 and 6 on the table for the median average payoffs). Lines 7 and 8 on the table show that the social-distance effects already appear at the first round; the proportion of subjects that played equilibrium strategies at round 1 was significantly higher with personal matching. The convergence rate to the symmetric patterns **AB**, **AABB**, **AAABBB** was 62.9% in the anonymous sessions compared to 71.4% in the personal sessions (see the bottom line on the table).

Table 7
Comparison of anonymous and personal designs

	Anonymous	Personal	Significance
Strong-convergence rate	40.8%	53.5%	$\alpha = 0.03$
Weak-convergence rate	52.4%	63.6%	$\alpha = 0.05$
LEP rate	4.8%	6%	n.s.
Avg weak-convergence round	9.11	8.81	n.s.
Median Rows payoff	106.85	117.37	$\alpha = 0.06$
Median Cols payoff	97.03	108.58	$\alpha < 0.05$
Starting with (A, A)	26.2%	40.4%	$\alpha = 0.06$
Starting with (B, B)	14.6%	20.2%	n.s.
Convergence to symmetric patterns	62.9%	71.4%	$\alpha < 0.05$

The significance levels on the third row are for: standard Z-tests for testing the equality of independent proportions; Mann–Whitney tests for comparing the average payoffs ($N = 202$) and the weak-convergence dates ($N = 117$).

More interestingly, we observe the following social-distance effects on the behavior of individual subjects:

5.1. The proportion with which subjects played their favorite strategies before weak convergence were significantly higher with anonymous matching.[24] In particular, Rows played B in about 53% (1266/2400) of the rounds before weak convergence in the anonymous treatments compared to a rate of 51% (968/1891) in the personal treatments. The corresponding rates for Cols are 55% (1331/2400) and 52% (989/1891).[25]

5.2. Subjects broke equilibrium patterns more frequently with anonymous matching. The number of broken patterns in the anonymous treatments was 136; compared to 107 in the personal treatments. The inclination to "break your favorite equilibrium pattern" however was stronger with personal matching. Subjects broke their favorite patterns 22 times with anonymous matching compared to 30 such occurrences in the personal treatments. The number of cases where subjects broke their partner's best pattern, on the other hand, was 82 in the anonymous treatments compared to 55 in the personal treatments. Again these comparisons suggest that subjects break their favorite equilibrium because of other-regarding-behavior type of motives, as discussed in Section 4.3 above.

5.3. Subjects were more inclined to play their favorite strategies after earning a disagreement payoff (30), with anonymous matching. In the anonymous treatments row-players chose B in $695/1090 = 63.7\%$ of the rounds following unsuccessful coordination. The corresponding proportion for the personal treatments was only $495/895 = 55.3\%$. Similarly, the rates with which col-players played A after unsuccessful coordination were: $700/1090 = 64.2\%$ (anonymous treatments) and $535/8955 = 5.97\%$ (personal treatments).[26]

6. Gender effects

Table 8 gives the convergence rates and the composition of patterns adopted in the four treatments. The numbers reveal a surprising significant gender effect on convergence rates with anonymous matching. The weak (strong) convergence rate in the anonymous row-player-male treatment was 59% (44%) compared to corresponding convergence rates of 45% (37%) in the ARPF treatment. The gender effect however disappeared with personal matching: the weak-convergence rate in the PRPM treatment (63%) for example was not significantly different from the corresponding rate for the PRPF treatment (64%).

[24] To calculate these proportions we truncate the observed play of each pair at the weak-convergence date. The data for pairs that did not converge is not truncated. The (36) pairs that have weakly converged in round 1 are not included.

[25] Mann–Whitney statistics (for the pair-level data; $N = 166$): $Z = 1.639$; $\alpha = 0.05$ for the first comparison; $Z = 2.296$; $\alpha = 0.01$ for the second.

[26] Mann–Whitney statistics (for the pair-level data; $N = 183$): $Z = 3.802$; $\alpha < 0.01$ for the first comparison; $Z = 0.88213$; n.s. for the second.

Table 8
Convergence rates and patterns adopted

Treatment	N	SCR (%)	WCR (%)	LEP (%)	**A**	**B**	**AB**	Other
ARPM	54	44	59	5.5	11	4	14	3
ARPF	49	37	45	4	1	4	15	2
PRPM	46	54	63	11	5	2	18	4
PRPF	53	53	64	2	6	5	20	3

Table 9
Playing favorite strategies before convergence

Treatment	Rows playing B	Cols playing A
ARPM	56.1% (639/1139)	58.1% (662/1139)
ARPF	49.3% (622/1261)	53.4% (673/1261)
PRPM	50% (428/855)	53.2% (455/855)
PRPF	52.1% (540/1036)	51.5% (534/1036)

A closer look at the composition of patterns-adopted (see Table 8) reveals that the difference in convergence rates across the two anonymous treatments mainly follows from the high convergence rate to **A** in the first case. In particular, **A** was adopted 11 times; i.e., in 34.4% of the 32 weak-convergence cases in the ARPM treatment while it was adopted only once in the 22 weak-convergence cases in the ARPF treatment. In the next paragraphs we give two explanations (at the level of individual behavior) for this surprising difference.

Consider first the proportion with which subjects played their favorite strategies before weak convergence (see footnote 24). Table 9 shows that in the ARPM treatment, females (acting as col-players) picked their favorite strategy A in 58.1% of the rounds before convergence. A pair-level Mann–Whitney test suggests that the proportions with which females play A before convergence in the ARPM-treatment are significantly higher than the proportions with which they play their favorite strategy B before convergence in ARPF-treatment ($N = 92$; $Z = 3.11$; $\alpha = 0.001$). Similar comparisons suggest that the proportions with which females play A before convergence in the ARPM-design are also significantly higher than the proportions with which males pick their favorite strategies (before convergence) in both ARPM and ARPF treatments.[27] The increased convergence rate to **A** in the ARPM treatment might thus follow from the relatively strong inclination of female subjects to play their favorite strategy when assigned to the inferior col-player role (with anonymous matching).

Consider next the proportions with which the equilibrium patterns **A** and **B** were broken in each treatment, as described in Table 10. To calculate these proportions, say the equilibrium pattern p has emerged $m = m_1 + m_2$ times in treatment j iff p was broken by at least one player (possibly by both) m_1 times in the sessions conducted in treatment j

[27] Wilcoxon signed-rank test; $N = 35$; $Z = 1.768$; $\alpha = 0.03$; for the first comparison. Mann–Whitney test $N = 92$; $Z = 2.2841$; $\alpha = 0.011$; for the second comparison.

Table 10
Broken patterns

Treatment	**A**	**B**
ARPM Rows	$25/37 = 67.57\%$	$6/25 = 24.00\%$
ARPM Cols	$4/37 = 10.81\%$	$20/25 = 80.00\%$
ARPF Rows	$21/23 = 91.30\%$	$8/26 = 30.77\%$
ARPF Cols	$4/23 = 17.39\%$	$16/26 = 61.54\%$
PRPM Rows	$14/25 = 56\%$	$5/19 = 26.32\%$
PRPM Cols	$8/25 = 32\%$	$13/19 = 68.42\%$
PRPF Rows	$16/25 = 64\%$	$11/24 = 45.83\%$
PRPF Cols	$6/25 = 24\%$	$12/24 = 50\%$

and p was adopted in the sense of strong convergence by m_2 pairs in treatment j.[28] Then calculate the ratio of (the number of times the pattern p was broken in treatment j) to the (number of times p has emerged in j).

The table shows that in the ARPM treatment, male row-players broke the female's best pattern **A** in 25 of the 37 cases (67.57%) in which it has emerged. In the ARPF treatment on the other hand, female row-players rejected the male's best pattern **A** in 21 of the 23 cases (91.30%) in which it has emerged. A pair-level Mann-Whitney test confirms that the proportions with which females break **A** in the ARPF treatment are significantly higher than the proportions with which males break **A** in the ARPM treatment ($N = 40$; $Z = 1.5736$; $\alpha = 0.0577$).[29] The difference in convergence rates to **A** in the anonymous treatments might thus also be attributed to some willingness of row-player males to accept the female's best pattern compared to a strong rejection of the male's best pattern by females at the row-player role.

Recall now (see Table 8) that the gender effects did not appear with personal matching.[30] In particular, the number of pairs converging to **A** was 5 in the PRPM design and 6 in the PRPF treatment. Thus, in the RPM treatments, the convergence rate to **A** has dropped from $11/32 = 34.3\%$ (with anonymous matching) to $5/29 = 17.2\%$ (with personal matching); while in the RPF treatments, the corresponding convergence rate has increased from $1/22 = 4.55\%$ to $6/34 = 17.6\%$. Again, the numbers on Tables 9 and 10 may explain the differences.

First note (see Table 9) that the proportion with which female col-players play their favorite strategy A before weak convergence has significantly decreased from 58.1% in the ARPM treatment to 53.2% in the PRPM treatment (pair-level Mann–Whitney test; $N = 77$; $Z = 2.373$; $\alpha = 0.01$). This may explain the decrease in convergence rates to **A** in the move from anonymous matching to personal matching with row-player males.

[28] We adopt this shortcut calculation to avoid additional definitions. The underlying idea is that whenever a pattern "emerges" (i.e., appears several times successively) it must either be broken or the conditions for strong convergence should apply.

[29] Pairs for which the pattern did not emerge were removed from the sample.

[30] See Rows 3–4 on the table for the distribution of patterns adopted in the PRPM and PRPF treatments. A Kolmogorov–Smirnov test suggests that the differences are not statistically significant ($D = 0.08$).

Secondly note that (see Table 10) the proportion with which female row-players broke the male's best pattern **A** has significantly decreased from $21/23 = 91.30\%$ in the ARPF treatment to $16/25 = 64\%$ in the PRPF treatment (pair-level Mann–Whitney test; $N = 32$; $Z = 1.6018$; $\alpha = 0.0546$). This may explain the increase in convergence rates to **A** in the move from anonymous matching to personal matching with row-player females.

No other significant gender affects were observed except for the following two points:

(1) Female subjects initiated convergence in 25 of the 117 cases in which weak convergence occurred. Male subjects initiated convergence in only 18 cases.
(2) While male subjects broke the females' favorite singleton pattern in 67 of 112 cases (59.8%) in which such patterns emerged, females broke the male's favorite singleton pattern in 70 of the 92 cases (76.1%) in which such patterns emerged (see the figures in Table 10).

7. Concluding discussion

We have analyzed the repeated play of a modified BoS from the perspective of strategic pattern recognition. The definitions used in the analysis are arbitrary as one must adopt specific cutoff levels when talking about appearance or convergence to patterns in finite histories. The results however are robust with respect to the chosen definitions. For example, if we require that the adopted pattern covers at least the last 8 rounds of the observed game (while still allowing for 20% disruption rate as in the original definition), the weak-convergence rate only drops down to 54% (109 pairs of 202) compared to 58% (117 pairs of 202) in the original formulation. At the same time, adopting stricter general conditions for weak or strong convergence would have excluded some cases that may intuitively fit the idea of convergence to a pattern. In one of our observations, for example, Cols played A successively while Rows repeatedly alternated between A and B from round 15 to round 30; Rows however gave up at round 31 and both players played A repeatedly in the last 4 rounds (the game was ended in round 34).[31]

We now briefly discuss some of the results:

(1) Subjects demonstrate regard for their partners by breaking their favorite equilibrium pattern when the payoffs of their partners are relatively low. The price of breaking your best pattern is relatively expensive in our game: at least 103 for Rows; at least 69 for Cols. Still, subjects broke their best patterns 52 times along the experiment. The behavior is more prevalent with personal matching. As an interpretation, it may suggest that social preferences can be strong enough to "kill" emerging conventions.

(2) Subjects' overall performance in the repeated game varies with the strategy profile played at the first round of the game. Subjects that started the game with equilibrium **B** converged to **A** in only 4 cases. Subjects that have opened with **A** have never adopted equilibrium **B**. This suggests that the role of independent random noise in the dynamics of

[31] Session 8; pair 1; ARPM treatment.

repeated interaction is limited and the outcome of the repeated game depends, to a large degree, on the choices made at the first round of play.

(3) Subjects that insist on teaching their partners to play their chosen pattern, pay a price in the sense of obtaining significantly lower average payoffs than those subjects that otherwise converge.

In addition we find that subjects' cooperative inclinations are significantly weaker with anonymous matching. This translates into lower levels of coordination and weaker performance in the anonymous-matching designs. If the anonymous-matching design approximates Web-based (anonymous) coordination tasks, then our results suggest that the Internet might have a significant negative effect on the coordination levels of economic agents (see (Birnbaum, 2000; Charness et al., 2001; Frohlich and Oppenheimer, 1998; Shavit et al., 2001) for some references on the Internet effects on decision making and economic interaction).

We also observe that female subjects are more affected by social distance than males.[32] In particular, our female subjects were strongly inclined to play their favorite strategy when assigned to the inferior role and to reject the male's favorite equilibrium when assigned to the superior role—in the anonymous matching designs. These behaviors either disappear or get milder with personal matching. This intriguing result should obviously be taken with due precaution. In particular, note that the population of subjects employed consisted of engineering students from one of the leading universities in Israel. In addition note that we did not test the performance of same-gender pairs and did not implement a double-blind treatment where subjects are not aware of their partner's gender. These extensions are left for future research.

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Appendix A. Translated instructions

- Welcome to the Experiment.
- You are about to participate in a decision-making experiment.
- In the course of the experiment you will be asked to play a given game repeatedly with a fixed partner for 30–40 rounds.
- Before the beginning of the experiment you will be asked to fill in a personal-details questionnaire.
- After you and your partner fill in the questionnaires, each of you will be asked to examine the form filled in by his/her partner.

[32] For a sample of other references on gender effects in coordination games, see Holm (2000), Eckel and Grossman (2000), Ortman and Tichy (1999).

– These personal details will show up on your screen all through the experiment.[33]

Instructions for the players selecting the rows

– You are about to play the following game:
– You and your partner have to simultaneously choose A or B.
– If you and your partner choose A your payoffs are 95 for you and 168 for the other player.
– If you and your partner choose B your payoffs are 198 for you and 99 for the other player.
– If the two of you do not choose the same strategy each of your receives a payoff of 30.
– Your payoffs are marked blue in the following payoff matrix and the other player's payoffs are marked red (at this point the instructions presented the game as in Fig. 1 with the payoffs marked in different colors).
– At the end of the experiment we will pay you $1/4$ of your average payoff along the game. For example, if you have earned an average payoff of 180 you will receive 45 NIS.

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[33] For transcripts of the experiment' screens see Sonsino's homepage at http://ie.technion.ac.il/sonsino.phtml.

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