Coordination and Information in Critical Mass Games: An Experimental Study[1]

Giovanna Devetag

Department of Management and Computer Science
University of Trento

Final version: July 2002
Forthcoming: *Experimental Economics*

Abstract

We present experimental results on a repeated coordination game with Pareto-ranked equilibria in which a payoff from choosing an action is positive only if a critical mass of players choose that action. We design a baseline version of the game in which payoffs remain constant for values above the critical mass, and an increasing returns version in which payoffs keep increasing for values above the critical mass. We test the predictive power of security and payoff-dominance under different information treatments. Our results show that convergence to the payoff-dominant equilibrium is the modal limit outcome when players have full information about others' previous round choices, while this outcome never occurs in the remaining treatments. The paths of play in some groups reveal a tacit dynamic coordination by which groups converge to the efficient equilibrium in a step-like manner. Moreover, the frequency and speed of convergence to the payoff-dominant equilibrium are higher, ceteris paribus, when increasing returns are present. Finally, successful coordination seems to crucially depend on players' willingness to signal to others the choice of the action supporting the efficient equilibrium.

1 Introduction

The notion of *critical mass* bears an intuitive meaning in everyday language, usually evoking the idea of some major change or discontinuity that occurs once a certain "threshold" is reached. Schelling (1978) was among the first to point out the pervasiveness of 'critical mass' mechanisms in phenomena pertaining to the social sciences, explaining a vast array of real-world examples (ranging from micro-events such as street crossing or meeting attendance, to macro-phenomena like racial segregation or housing migration) in terms of families of models involving some activity that becomes self-sustaining once a minimum threshold is reached. Although Schelling's examples of aggregate behavior phenomena did not include the class of market interactions, critical mass principles have increasingly attracted economists' interests as well. Models of technological competition embedding positive 'installed base' effects (Farrel and Saloner, 1986), models of standard adoption that link the diffusion of new standards to the existence of a threshold number of adopters (e.g., Granovetter and Soong, 1986; David and Greenstein, 1990 for a review) are just some examples. Schelling's analysis also pointed out that, in general, critical mass effects may be associated to positive feedbacks or *increasing returns*, implying that, once a threshold is reached, the more individuals engage in some activity, the more others will be inclined to do the same.

In this work we undertake an experimental study of critical mass and increasing returns effects in strategic settings. We design a simple N-player coordination game with multiple, Pareto-ranked equilibria whereby individual payoffs depend on critical numbers of players choosing certain actions, with and without the addition of increasing returns in the number of players choosing the same action above the critical value. We run experiments to test which equilibrium, if any, is selected when fixed groups of players are allowed to play for a certain number of rounds. In doing so, we run different treatments in which we vary the amount of information that players have after each round of play. The motivations of the work are twofold: first, we intend to add experimental evidence to the problem of equilibrium selection in games with multiple equilibria: since the seminal works of Van Huyck, Battalio and Beil (1990, 1991), several experiments onWe present experimental results on a repeated coordination game with Pareto-ranked equilibria in which a payoff from choosing an action is positive only if a critical mass of players choose that action. We design a baseline version of the game in which payoffs remain constant for values above the critical mass, and an *increasing returns* version in which payoffs keep increasing for values above the critical mass. We test the predictive power of security and payoff-dominance under different information treatments. Our results show that convergence to the payoff-dominant equilibrium is the modal limit outcome when players have full information about others' previous round choices, while this outcome never occurs in the remaining treatments. The paths of play in some groups reveal a tacit dynamic coordination by which groups converge to the efficient equilibrium in a step-like manner. Moreover, the frequency and speed of convergence to the payoff-dominant equilibrium are higher, *ceteris paribus*, when increasing returns are present. Finally, successful coordination seems to crucially depend on players' willingness to signal to others the choice of the action supporting the efficient equilibrium. coordination games have shown that the equilibria that are selected through repeated interaction strongly depend on both structural and contextual factors (e.g., labelling of strategies, the type of strategic complementarity implied by the payoff function, the number of rounds, the amount of information feedback; see next section). Hence, the question on the relative predictive power of different selection principles in games with multiple equilibria still remains open and deserves empirical investigation; in this work, we study the salience of selection principles in a game in which the payoff structure is such that payoffs to players depend on absolute frequencies of players choosing a certain action, which renders it different from other coordination games studied so far. Second, we intend to explore, within the specific framework of this game, the impact of different information treatments on players' behavior. Our main results can be summarized as follows: first, convergence to the payoff-dominant equilibrium is the modal limit outcome when players have full feedback about others' previous round choices, while such an outcome is never achieved in the remaining treatments. Second, the frequency and speed of convergence to the efficient equilibrium are higher, *ceteris paribus*, when increasing returns are present. Finally, successful coordination seems to crucially depend on players' willingness to signal to others the choice of the action supporting the efficient equilibrium.

The paper is organized as follows: section 2 reviews previous literature on coordination games with Pareto-ranked equilibria; section 3 presents the critical mass game in its baseline version and in the version with increasing returns, and describes the experimental design; sections 4 and 5 discuss the results, and section 6 offers some concluding remarks.

2 Background

One of the major interests in empirical investigations of coordination games stems from the fact that purely theoretical considerations fall short of predicting which of the many equilibria players will select as the solution. While n-player coordination games with multiple, Pareto-equivalent equilibria typically result in coordination success (e.g., the extensive literature on market entry games; Erev and Rapoport, 1998), in games in which equilibria can be Pareto-rankable coordination failure in the laboratory is far from uncommon.

Interesting games belonging to the latter class are *order statistic* games, first studied by Van Huyck, Battalio and Beil (1990). In these games, players must choose numbers in a certain range (where numbers usually symbolize different effort levels), and their individual payoff is a function of both their own choice and of an order statistic (e.g., the minimum or the median) of all numbers chosen in the group. Payoffs rise with the order statistic but decrease in the distance of the number chosen from the order statistic. All such games present a multiplicity of strict equilibria which can be Pareto-ranked, and are generally meant to reflect economic situations that present strategic complementarities (e.g., Cooper, 1999).

The results obtained in the experiments by Van Huyck et al. are quite robust and can be roughly summarized as follows: with large groups (typically groups of 9 in the median game and groups of 14-16 players in the minimum game), and with baseline information treatments (i.e., only the minimum or median is publicly announced after each period) there is a relatively high frequency of both disequilibrium outcomes and coordination failure. However, while the limit outcome in median action games (which is usually an inefficient equilibrium of the stage game) is completely determined by the historical accident of first period play, in minimum action games first period play has no influence; rather, a downward drift to the most inefficient outcome almost invariably occurs[2].

Allowing more information to be shared by players (such as, for example, announcing the entire distribution of choices in the minimum effort game) had a negative effect in their experiments, in that it only speeded up convergence to inefficient equilibria (Van Huyck et al., 1990).

While the original Van Huyck et al.'s design implied the choice between seven effort levels, Van Huyck, Battalio and Rankin (2001) introduced a very fine grid intended to approximate a continuous action space (strategies available to players were 100 instead of 7) and varied some treatment variables such as order statistic and group size. Their results partly differ from their original experiments: In particular, in the median treatment with a group size of seven, some cohorts exhibit an upward drift in efforts in the direction of the Pareto-optimal outcome, which never occurred in their original treatment. The authors attribute this effect to the lower cost of local experimentation induced by the finer grid, which induced some players to explore in the direction of efficiency.

Several other studies have investigated the conditions that might affect coordination in order statistic games. Van Huyck, Battalio and Beil (1993) have imposed participation costs to players such as to rule out inefficient equilibria by forward induction. Berninghaus and Ehrhart (1998) have proved that an extended time horizon improves coordination in the minimum effort game. Keser, Ehrhart and Berninghaus (1998) have shown that the nature of interaction (local versus global) also matters in determining which equilibrium will be selected. Goeree and Holt (1999) have shown that changes in the payoff function such as reducing the costs of deviation from equilibrium play, substantially improve coordination in the minimum effort game. Bornstein, Gneezy and Nagel (1999) have obtained similar results by introducing forms of inter-group competition. Allowing pre-play costless signaling was shown to increase efficiency in the median action game (Blume and Ortmann, 2000). Overall, these studies highlight that convergence to efficient equilibria in coordination games is far from trivial. At the same time, there are several conditions that improve the efficiency of the achieved coordination, either by increasing the individual incentive to engage in risky explorations, or by allowing players to influence each other's beliefs and actions through their choices. However, the type of strategic complementarity imposed by the payoff function also matters, given, for example, the different results obtained in the minimum and median effort games.

Other studies have investigated the role of information feedback on behavior in other classes of games. Duffy and Feltovich (1999) explore learning in the repeated ultimatum games and the repeated best-shot games under the conditions in which dyads may observe the actions and payoffs of another randomly chosen dyad after each round of play. Duffy and Hopkins (2001) study learning in market entry games under different information feedback conditions. Duffy and Feltovich (2000) compare cheap talk and information about actions of others as means to improve efficiency and cooperation in three one-shot games. Not surprisingly, the amount of information available to subjects does influence their behavior, although such differences tend to be game-specific, and not necessarily efficiency-enhancing, given the early results of a full information feedback in the experiments by Van Huyck et al.

3 The Critical Mass game

The game-theoretic framework

The dependence of payoffs upon critical masses is rendered via the introduction of *thresholds* (expressed in terms of numbers of people), below which players who choose a certain action are not rewarded[3].

In the baseline version of the Critical Mass game, N players must at each round privately and independently choose one and only one number in a certain range $(1, I)$. The payoff from picking number $i \in (1, I)$ is the same for all players and is determined as follows:

$$\pi_i = \begin{cases} \alpha i & \text{if } n_i \geq i \\ 0 & \text{otherwise} \end{cases} \tag{1}$$

where $n_i \leq N$ is the number of players who choose number i, and α is a positive constant. In descriptive terms,

- each player's payoff increases monotonically with the number chosen, conditional on the threshold associated with that number being matched
- higher numbers require higher thresholds (i.e., they require more players picking them) in order to yield positive payoffs

The foregoing payoff function is designed so that once the threshold is reached in correspondence of a particular number, payoffs remain constant if additional players join.

In the second version of the game, Increasing Returns, given that the threshold for a number is matched, the individual payoff is higher the more players choose it:

$$\pi_i = \begin{cases} \alpha i + n_i - 1 & \text{if } n_i \geq i \\ 0 & \text{otherwise} \end{cases} \tag{2}$$

Now, given that the threshold is reached, individual payoffs associated with a number increase by one unit as each additional player joins.

Real world examples of the Critical Mass game include, e.g., choices among different technologies some of which are more efficient than others but require a larger 'installed base' of adopters, due to the existence of network effects; choices among different activities which are more or less enjoyable but which require different threshold number of participants to be implemented (I can rent a movie and watch it at home alone, but I need a partner to play tennis, and 21 partners to play soccer). A little more metaphorically, passing from low to high numbers may symbolize increasing degrees of standard adoption in a market; standardization of practices and products usually increases efficiency but requires a large installed base of users to coordinate on the same standard, otherwise lack of standardization is preferred[4].

The addition of *increasing returns* is justified on the ground that in general, critical mass effects are associated with increasing returns (Schelling, 1978). In fact, both phenomena often derive from the presence of *network* or *participation* externalities, whereby the utility of acquiring a particular good or technology, or of undertaking a specific activity is higher for the individual, *ceteris paribus*, the higher the number of other buyers of the same good or participants to the same activity (e.g., Farrel and Saloner, 1986; Katz and Shapiro, 1986). The case of the threshold effect depicted in eq. (1) can be considered as a specific instance of increasing returns, in which the utility does not increase further once a minimal threshold is satisfied.

From a game-theoretic standpoint, the addition of increasing returns in the payoff function does not change the set of equilibria selected by efficiency and security with respect to the baseline version. What about its effects on actual behavior in a strategic interaction setting? Brian Arthur (1994) tried to formalize the dynamic effects of increasing returns in an economic system in which individuals choose myopically and with limited information between available options, and he found out a strong dependence of the final outcome on initial conditions, which allow for the possibility of lock-in on inefficient equilibria. However, the effects of increasing returns in a strategic setting in which players have common knowledge of the payoff function and full information about other players' past choices needs not necessarily yield the same results. Hence, the behavioral effects of introducing increasing returns in our game with respect to the baseline payoff function cannot be hypothesized ex-ante based on theoretical considerations.

Although there is no *a priori* reason to require that the number of strategies available to each player equals the number of players in the group, we will from now on restrict it to the case in which $N = I$. In this case, the critical mass required to gain the payoff implied by the efficient equilibrium corresponds to the totality of players in the group.

Equations 1 and 2 give rise to the payoff tables 1 and 2 for the simple case in which $N = I = 7$, and $\alpha = 1$.

insert Tables 1 and 2 about here

The tables' rows report each player's available strategies, that is integers from 1 to 7. Columns report, for each integer, the total number of players who pick that integer. It is straightforward to see that the games have seven strict Nash equilibria in pure strategies, corresponding to the seven action combinations in which all players pick the same number. The equilibria can be Pareto-ranked: the $n-tuple(7, \dots 7)$ is the equilibrium selected by efficiency or payoff-dominance, while security would select the $n-tuple(1, \dots 1)$, which corresponds to the situation in which all players choose their secure strategy.

The basic design feature of the games is the existence of a graded interdependence among players' choices of number, which is expressed in a hierarchy of critical masses, so that the achievement of Pareto-superior outcomes requires increasing degrees of coordination, and the achievement of the best outcome requires all players in a group to be coordinated on the same action. Hence, the need for coordination is stronger the higher the potential reward.

Information Treatments

In order statistic games, the best response is always to pick a number equal to the order statistic. Accordingly, in most experiments, the order statistic was announced at the end of each round, so that players could form beliefs about the next period order statistic based on its current value. In the Critical Mass game no statistical indicator is available which conveys all the information necessary to pick a best response to other players' previous round choices, hence the entire choice distribution must be announced. However, announcing the entire choice distribution not only has an informative value for the players: It also represents a potentially powerful coordination device as some players may be induced to pick high numbers as a "signal" to others. Although signaling may in principle occur even in treatments in which only the previous round order statistic is announced, such a possibility is considerably enhanced by a full information condition. Therefore, varying the information condition allows us to disentangle the effects of information feedback from those related to the game's payoff structure. For such reason, we ran a second information treatment in which subjects knew only the median of previous round choices (MEDIAN treatment), and a third treatment in which subjects knew only their own previous round payoff (PAYOFF treatment).

Experimental design and implementation

In the experiment fixed cohorts of seven players interacted for 14 periods. The number of periods was always known in advance to players, while the amount of information available after each round of play was varied. In all treatments subjects received additional feedback about their own payoff in each round.

Table 3 summarizes the three information treatments, and the number of cohorts within each treatment.

insert Table 3 about here

Due to the high number of subjects required, the three information treatments were tested only for the Critical Mass game in this first round of experiments, while only the FULL INFORMATION condition was tested for the Increasing Returns game.

All experiments were conducted at the Computable and Experimental Economics Laboratory (CEEL), at the Department of Economics of the University of Trento. All subjects who participated were undergraduate students enrolled in the Economics, Law, Literature, Mathematics, Physics and Sociology programs, and were recruited through ads posted at the various Department buildings. Various sessions were conducted, and subjects were randomly assigned to the different treatments. The payoff tables used were the ones shown in table 1 and 2.

Payoffs were always expressed in 'experimental points', to be converted into cash at the end of the experiment. Subjects received a fixed show up fee plus anything they could earn in the game. Sessions lasted about 40 minutes on average. All sessions lasted less than an hour. Average earnings were equal to 18 euros, maximum earnings were equal to 25 euros, minimum earnings were equal to 9.3 euros. Minimum earnings were realized in the MEDIAN and PAYOFF sessions only, which lasted half an hour on average. That means a *minimum* earning of 18.6 euros per hour[5]. The point/EURO exchange rate was assigned different values depending on the payoff function and on the treatment, in the effort to keep the maximum theoretically achievable earnings constant across sessions.

Upon arrival, subjects were randomly assigned seats at computer terminals which were separated from one another by wooden screens. No form of communication was allowed from the moment subjects were seated. Although the experiment itself was computerized, each subject received a paper copy of the payoff table and a paper copy of the instructions, which were read aloud at the beginning of the session to assure that the game's rules were public knowledge[6]. After reading the instructions but before the experiment began, subjects had to fill in a paper questionnaire to assure that they had understood how to calculate points according to the payoff table. The questionnaire was then given back to the experimenter, and if there were any incorrect answers instructions were read again. Subjects made their choices by computer. When all players in a group had entered their choice for that round, the computer would calculate individual payoffs and communicate them to players together with the additional information prescribed by the experimental treatment. Information regarding each round of play remained visible on each player's screen for the entire game duration.

4 Results: Aggregate

First period choices

Table 4 reports mean, standard deviation and full distribution of choices in the first period of the game separately by treatment and by payoff function (Critical Mass and Increasing Returns).

insert Table 4 about here

First, data show that efficiency dominates security in all treatments. However, the action implementing the efficient equilibrium is far from capturing all or even the majority of players' choices. In fact, 149 out of 238 subjects (62.7%) select an action *other* than those implied by efficiency and security, confirming previous results on analogous games. Most of such choices, moreover, are concentrated on the two numbers 3 and 4. Second, the percentage of subjects picking 7 in the Increasing Returns game is almost doubled compared to that in the Critical Mass game in the FULL INFORMATION treatment. However, pairwise comparisons of the choice distributions made by applying a nonparametric Kolmogorov-Smirnov test found no significant differences in the choice distributions. The absence of any significant difference suggests that players in the first round of play do not realize or do not take advantage of the signaling ability provided by the full information condition.

Equilibrium and dynamics analysis

Seven out of twelve cohorts converge to the payoff-dominant equilibrium in the Critical Mass FULL INFORMATION game, and nine out of twelve do so in the Increasing Returns FULL INFORMATION game. Among the remaining cohorts, seven converge or almost converge[7] to an inefficient equilibrium (either 3, 4, or 5), and one shows a disequilibrium outcome. No convergence to the payoff-dominant equilibrium is observed in the remaining treatments. In particular, in the PAYOFF treatment, two cohorts almost converge to 3, while the remaining cohorts end up in a disequilibrium outcome. In the MEDIAN treatment, convergence or almost convergence to either the 3 or 4 equilibrium is observed.

Hence, sharing full information about past action choices favors coordination on the payoff-dominant equilibrium in the majority of groups, and such outcome occurs more often in the Increasing Returns game. It has to be noticed that no cohort converges to the secure equilibrium.

To have a summary view of the type of dynamics leading to equilibrium, table 5 reports, separately for each cohort, the sequence of modal choices over time for the Critical Mass and

Increasing Returns games in the FULL INFORMATION treatment, highlighting whenever the *threshold* for that number was matched (i.e., whether a number of players at least equal to the threshold picked that number), and whether a mutual best response outcome occurred. Tables 6 and 7 report the same information regarding the PAYOFF and MEDIAN treatments respectively.

insert Tables 5, 6 and 7 about here

The FULL INFORMATION treatment Results in the FULL INFORMATION treatment reveal a quite interesting behavioral pattern. In the Critical Mass game, out of the seven cohorts that reach the Pareto-efficient equilibrium, only cohort 6 does so by the end of the first seven periods of play. The other groups reach this outcome gradually. In particular, cohorts 2, 4, 5, and 7 creep up towards the efficient equilibrium in a fairly well coordinated way, as shown by the sequence of modal choices over time. The modal choice increases by one level per time in groups 2, 4, 5 and 7, suggesting that a dynamic convention develops by which groups reach the Pareto-optimal equilibrium in a step-like manner (Fig. 1 and 2 show modal choices graphically for two of these cohorts; in the two groups the dynamics of modal choices over time look remarkably similar).

insert Fig. 1 and 2 about here

Groups 2 and 7 are also able to 'unlock' from inefficient equilibria. Finally, in cohort 9 and 12, the modal choice increases by three and two levels at the time respectively. Hence, repeated play in some groups seems to induce the mutual expectations that the next period mode will be higher than the previous period mode. This path of play recalls a similar dynamic found in experiments by VanHuyck, Battalio and Rankin (1996) with a fine grid, in which some cohorts moved towards efficiency increasing the order statistic by a fixed amount each period.

In the Increasing Returns game with full information, coordination on the payoff-dominant equilibrium is more frequent than in the Critical Mass game; in addition, the speed of convergence is higher as well. In fact, of the nine cohorts converging to the Pareto-optimal outcome, seven (1, 3, 4, 9, 10, 11, 12) manage to do so by the end of the first seven rounds of play. Three of these (3, 11, 12) already converge by period three. Group 5 gradually raises the mode from 5 to 6, then converges at the 6 equilibrium and manages to move away from it reaching the 7 equilibrium by the eleventh round. Among the groups not reaching the optimum, group 2 and 8 get 'locked-in' at the 4 and 5 equilibrium respectively, and cohort 7 ends up in a disequilibrium outcome after the mode has slowly increased from 3 to 6.

The PAYOFF and MEDIAN treatments Inspection of modal efforts over time in the PAYOFF treatment reveals that in the absence of any shared information about the game history, coordination on *any* equilibrium is difficult to reach in the game. A mutual best response outcome never occurred in this treatment. Modal choices are mostly concentrated around the 3 value, with some occurrence of 7 (especially in cohort one), and do not increase over time. The fact that no convergence to the secure equilibrium is observed may be due to the low relative attractiveness of the secure payoff *per se*[8], or to players' being sensitive to the opportunity cost of playing the secure action in a condition in which other players were possibly coordinating on higher numbers. Hence, subjects may have kept exploring the strategy space in the effort to 'spot' the other players' location.

Results in the MEDIAN treatment reveal that groups seem to use the median as a coordination device to reach mutual best response outcomes, and the type of dynamic is similar to that observed in the median action game (Van Huyck et al., 1991); in fact, except in cohort 1, in which the mode keeps fluctuating, in the remaining groups from period 4 onward modal efforts become constant and always equal to the group *previous period* median (see table 6).

Some observations are noteworthy from the foregoing analysis of aggregate results. Most groups are able to converge to the payoff-dominant equilibrium in both the Critical Mass and Increasing Returns games when the entire choice distribution in the previous period is made public to players. In addition, the observed paths of play in this treatment suggest that a dynamic focal point (Schelling, 1960) emerges by which players move up towards efficiency in a step-like manner, revealing a form of tacit dynamic coordination which occasionally makes groups escape from inefficient equilibria. On the contrary, no convergence is observed when players have only private information, and information about the previous round median allows players to solve the individual coordination problem of matching other players' choices, but it is not sufficient to solve the collective coordination problem of reaching the efficient equilibrium.

Finally, the addition of increasing returns increases the rate and speed of convergence to the efficient equilibrium.

.

5 Results: Individual Behavior

In this section we analyze individual behavior in both the Critical Mass and Increasing Returns games in the FULL INFORMATION treatment by applying a simple adjustment rule derived from Learning Direction Theory (Selten and Stoecker, 1986). As it is well known, Learning Direction Theory is a qualitative theory of learning according to which players adjust their behavior from one period to the next on the basis of ex-post reasoning on what actions would have been better in the previous round (e.g., Mitzkewitz and Nagel, 1993; Nagel, 1995; Berninghaus and Ehrhart, 1998; Blume and Ortmann, 2000).

We distinguish between players who earned a positive payoff in a certain round of the game (i.e., players who succeeded in matching their action's threshold and hence to coordinate with a subset of the other players) and players who earned a payoff of zero. Accordingly, we formulate two adjustment rules:

- **Rule 1**: When a player gets a positive payoff from a certain number in a round (i.e., the threshold for that number is matched), he raises or at least does not reduce his or her number in the next round[9]

- **Rule 2**: When a player gets a payoff of zero from a certain number in a round, he picks a number *not lower* than the highest number that matched its threshold in the previous round

We replicated the analysis in Berninghaus and Ehrhart (1998), and counted the number of individual choices - except those that were part of the efficient equilibrium - conforming to rule 1 and 2 in each group.

Our variant of Learning Direction Theory fares rather well at capturing our experimental subjects' behavior, as the vast majority of the observed choices both in the Critical Mass (98%) and in the Increasing Returns game (98.8%) are consistent with the rules. However, what appears difficult to reconcile with directional learning is the systematic overshooting that was observed in some of the groups, as revealed by the aggregate analysis of results. Moreover, in the Increasing Returns game several rounds resulted in no threshold being matched, which makes it problematic to identify a 'target' for the players other than the secure strategy 1.

To gain some insight into the individual adjustment dynamics, in table 8 we also report, separately for the two games and for successful and unsuccessful cohorts, the percentages of choices that satisfied rules 1 and 2 with *strict inequality*, i.e., the percentages of times in which the positive payoff-players chose *higher* actions than their previously chosen action and the zero-payoff players chose *higher* actions than the previous period best action. Finally, we report the percentages of both positive and zero payoff players who picked the action supporting the efficient equilibrium, 7.

insert Table 8 about here

A comparison between the observed frequencies in the Critical Mass and Increasing Returns games across all cohorts by a robust rank-order test[10] reveals a significant difference in the behavior of the zero-payoff players, who chose 7 more often in the Increasing Returns game ($p-value = .0006$). In addition, both types of players appear significantly more willing to explore in the direction of efficiency in successful groups as compared to unsuccessful groups across the two games[11]. In particular, in successful cohorts both types of players pick 7 significantly more often[12]. Finally, the choice of action 7 by a player is overall more frequent after a zero-payoff round than a after a positive-payoff round[13].

Can standard models of learning account for this evidence? Learning Direction Theory is too undeterminate, since it only states the direction of change (allowing for inertia) without specifying either the magnitude or the speed of adjustment. Learning models based on simple reinforcement (Roth and Erev, 1998) would predict either convergence to inefficient equilibria or no convergence at all in the number of iterations fixed for our experiments, given the high incidence of zero-payoff rounds that were observed especially in successful cohorts.

Belief-based models (e.g., Fudenberg and Levine, 1998, out of an enormous literature) or hybrid models (Camerer and Ho, 1999) could partly explain the overshooting by assuming that players pay attention to the upward trend in choices and learn to anticipate it. However, if such belief-driven behavior was the only explanation, there should be no differences between the zero-payoff and positive-payoff players. In addition, while this explanation might account for the behavior of those players who were simply reacting to changes in their environment, it begs the question of how the upward trend emerged in the first place. Finally, the frequent choice of 7 could only be explained by assuming extremely optimistic beliefs, which seem scarcely plausible.

Rather, the frequent choice of 7 in a condition of full information suggests a simple explanation based on a form of sophisticated behavior by which players were trying to signal the choice of the efficient equilibrium to other group members in order to try to influence their behavior in that direction. The difference may then be explained by the lower opportunity cost associated with signaling for the zero-payoff players. As in Van Huyck, Battalio and Rankin's experiments, players appear to be more inclined to engage in experimentation, *ceteris paribus*, when the opportunity cost of experimentation is lower. In our experiments, some players were more willing to engage in signaling and by doing this to forego current payoffs in view of higher expected payoffs in later rounds. Other players were more prone to wait and join others only when it was profitable to do so.

6 Discussion and Conclusion

In this paper we explored dynamic coordination with different information conditions in a game that abstractly mirrors choices (between, e.g., standards, technologies, products, or social norms) that are characterized by critical mass and increasing returns effects. Our main results are that, first, a full information treatment enables groups to achieve coordination success in the majority of cases, and coordination is improved when increasing returns are added to the payoff function. Such a result is not obvious, given that the same treatment does not produce the same outcome in similar games. On the contrary, a median treatment allows groups to reach mutual best response outcomes using the median as a coordination device, but such outcomes are inefficient equilibria. Finally, a payoff treatment produces disequilibrium outcomes and large overall inefficiency. The analysis of the paths of play in the full information treatment shows the emergence of *gradualism* in the form of a dynamic focal point, by which some groups 'hill-climb' the strategy space one step at a time in a fairly well coordinated mode up to the efficient equilibrium, occasionally escaping from inefficient equilibria. Finally, coordination success depends on players' willingness to signal to others the choice of the action supporting the efficient equilibrium.

There is increasing evidence that when playing in fixed cohorts as opposed to random rematching, some players engage in 'strategic teaching' (Camerer and Ho, 2000), ie., they make choices that penalize their current payoffs with the expectation that other players will learn in subsequent rounds to play the strategy supporting the efficient equilibrium. With large groups, however, players may be willing to engage in teaching only if they have the possibility to signal through their choices of actions, as in our experiments. In fact, in both the other information treatments in which the signaling ability was substantially lowered, players behaved more myopically. In addition, having numerous 'zero-payoff' rounds seem to have favored signaling, by making it virtually costless for the zero-payoff players. Clark and Sefton (2001) find similar evidence of signaling behavior in two-player repeated games as opposed to one-shot, although their subjects exploit the signaling opportunity even in the first round of play. The larger group size used in our experiments might have made signaling appear ex-ante as less effective, explaining why it was not observed right from the start.

Finally, the results obtained in the Increasing Returns game deserve some discussion. It appears difficult to explain the difference in results between Critical Mass and Increasing Returns in the light of existing learning models. Crawford's model (1991) accounted for the different results observed in Van Huyck et al.'s minimum and median treatments by endowing players with idiosyncratic shocks to their beliefs that depend on the amount of strategic uncertainty and that can generate different dynamics depending on the payoff assignment rule. In the Increasing

Returns game a total lack of coordination was often observed in early rounds. While this might have considerably risen strategic uncertainty and hence the magnitude of players' shocks to beliefs compared to the Critical Mass game, it remains to be explained why such lack of coordination did not lead to sharp convergence on the secure action 1. Rather, the increased strategic uncertainty might have favored convergence to 7 by strengthening the incentive to signal and by making the efficient equilibrium an 'obvious' focal point in the absence of any other coordination device.

Finally, it remains to be explained whether it is the increasing returns nature of the payoff function or other elements like the relative attractiveness of the different actions to determine such result. Battalio, Samuelson and Van Huyck (2001) found that in laboratory stag hunt games with random matching, the pecuniary incentive to optimize (i.e., to best respond to others' behavior) determines changes in the speed of convergence and in the probability that the payoff-dominant equilibrium will emerge. The notion of optimization premium is not immediately extendible to the n-player, n-strategy ($n \geq 2$) case. However, their results point at the relevance of out-of-equilibrium payoffs to determine convergence in games of coordination (see also Goeree and Holt, 2001). Although the relative difference in payoff between the secure and the payoff-dominant equilibrium is lower in the Increasing Returns game than in the Critical Mass game, the relative difference between the payoff from picking the secure action when nobody else does and the payoff from the efficient equilibrium is higher. If players focused on these elements of the payoff table, then they had a higher perceived incentive in coordinating on the efficient equilibrium in the Increasing Returns game. Furthermore, the lower monetary value assigned to the experimental point in the Increasing Returns game could have further reduced the attractiveness of the secure strategy with respect to the Critical Mass game, and created a higher incentive for signaling.

Future research should address the effect of changes to the payoff function parameters so as to render the secure equilibrium relatively more attractive and to test whether more coordination on such equilibrium is observed.

Finally, more research is needed to understand the impact of structural factors like the type of complementarity upon the attained equilibria, and the behavioral and cognitive mechanisms leading to them.

Appendix: Instructions

The following is a translation of instructions given to subjects in the FULL information treatment. Instructions for remaining treatments as well as original instructions in Italian are available from the author upon request.
WELCOME!
You are about to participate in an experiment on decision making in contexts of interaction, in which your earnings will depend on your own decisions and on the other participants' decisions. If you follow the instructions carefully and make appropriate decisions, you will be able to earn an appreciable amount of money, which will be paid to you privately and in cash at the end of the experiment.

The full information treatment

INSTRUCTIONS
Each of you has been given three numbered sheets, which are identical for all participants.
In the following experiment you will participate in a "market" composed of **seven** participants. The market will last for a total of **14** periods. At the beginning of the experiment, you will be randomly divided into two group of seven participants. The two groups will remain the same throughout the 14 rounds. That is, each of you will be paired with the same six participants for the whole market duration; therefore, to avoid confusion, remember that when, in the remainder of the instructions, "other participants" will be mentioned, it will always mean only the persons of your group, and not the total of participants in the room.

In every period of the market, each one of you will be able to earn a certain number of "experimental points", which will be then summed up and converted in cash at the exchange rate of L. XX for each point.
The rules of the market are the following:
In each period, every participant will have to choose, in isolation from the others, one and only one integer from 1 to 7 (included). The points that each of you will earn in each period will depend on the number he or she has chosen and on the number of participants of her group who have chosen that number.

Each of you has been given a double-entry table which will help you calculate your earnings. The table is identical for all participants.

Please, now pay attention to the table (sheet N. 2). The **rows** of the table represent your feasible choices in each period, that is the integers from 1 to 7. The **columns** of the table represent, for each integer that you chose, the total number of participants of your group (yourselves included) who have chosen that number. The cells report the points that you earn in correspondence of every possible combination. The points that you earn, in other words, will lie at the intersection between the row corresponding to the integer that you have chosen and the column corresponding to the number of people in your group (from a minimum of 1 to a maximum of 7) who have chosen that integer.
The experiment will be conducted at the computer in the following way:
Please, now pay attention to your screen. Each of you sees a table with four columns. The first column on the left will indicate the *round* number (from 1 to 14). At the beginning of each round, each of you will have to type in the number he or she has chosen in the little window at

the bottom-right of the screen and then click with the mouse on the *your choice* button. The number you have chosen for that round will appear in the second column of the table. After you have made your choice, please wait in silence that other participants make theirs. After all seven participants have chosen their numbers, the computer will display the numbers chosen by all seven participants in the third column of the table, under the heading *choices*, and will automatically calculate each participant's earnings according to the double-entry table. The points that you have earned in that round will appear in the fourth column, under the heading *your payoff*.

At the end of each period, hence, the computer will let you know the entire sequence of numbers chosen in your group (your number included, of course), and your personal earnings. This information will remain visible for the entire duration of the market. You will always be able to check with the double-entry table that your points have been calculated correctly.

Only after this information will be displayed on your screen you will be allowed to make your choice for the following period.

WARNING N. 1. In order to assure the correct conduct of the experiment, it is absolutely necessary that you remain silent, never communicate with each other and never try to look at other people's work until the end of the experiment. If the administrator should notice any form of verbal or non-verbal communication, or any type of improper behavior (like talking loudly, shouting, etc.), the session will be immediately interrupted, and nobody will be paid. We thank you in advance for your cooperation. If, at any time, you have questions, please raise your hand, and one of the experimenters will come at your desk.

WARNING N. 2. There is no time limit for your choices. Hence you can take all the time you need to think, and you can also change your choice as many times as you want before clicking on the *your choice* button. After you click, your choice for that period cannot be changed anymore. We also remind you that the computer will not allow you to make your choice for the next period before the current period is completed.

In order to assure that everybody has correctly understood the rules of the market, we now kindly ask you to answer the questions reported on sheet N. 3, and to give the sheet back to the experimenter. Should there be incorrect answers, the experimenter will read the instructions again, and questions will be answered. Thank you.

QUESTIONNAIRE

The questionnaire serves the only purpose of assuring that everybody has understood the instructions before the experiment starts. Your answers to the questionnaire will not affect your earnings in any way.

Example: if you choose number 3, and the number of participants in your group who choose 3 is 5 (that is, yourself and other 4 participants), you earn X points (intersection between ROW 3 and COLUMN 5).

Question N. 1. Imagine to have chosen number 3 in a certain period. The complete series of the numbers chosen by the seven participants in that period is the following:

3 3 1 4 7 6 2

According to the table, how many points have you earned?

Question N. 2. Imagine to have chosen number 1 in a certain period. The complete series of the numbers chosen by the seven participants in the period is the following:

1 3 3 2 4 7 5

According to the table, how many points have you earned?

Question N. 3. Imagine to have chosen number 4 in a certain period. The complete series of the numbers chosen by the seven participants in the period is the following:

4 5 3 4 4 4 2

According to the table, how many points have you earned?

Question N. 4. Imagine to have chosen number 2 in a certain period. The complete series of the numbers chosen by the seven participants in the period is the following:

2 2 4 2 3 2 6

According to the table, how many points have you earned?

Now please, give the sheet back to the experimenter. Thank you.

Acknowledgments

I wish to thank Michele Bernasconi, Colin Camerer, Giovanni Dosi, Paul Ferraro, Luigi Marengo, Rosemarie Nagel, Charles Noussair, Nick Vriend, Massimo Warglien, participants to the ESA meetings in Grenoble and New York and several anonymous referees for useful comments and suggestions on a previous draft, Marco Tecilla and the CEEL staff for precious help in the implementation and carrying out of the experiments. Financial support from the Italian Ministry of Education, University and Research and from the Cognitive Science Laboratory of the University of Trento is gratefully acknowledged. The usual disclaimer applies.

Notes

[1]A previous version of this work appeared as working paper under the title "Coordination in Critical Mass Games: An Experimental Study".

[2]For a suggestive interpretation of the experimental results obtained by Van Huyck et al. via a stochastic learning model, see Crawford (1991).

[3]The idea of having collective outcomes depend on thresholds is certainly not new, and it has already been largely explored in the context of public goods games, many of which have a step-level structure which renders them *de facto* coordination games (e.g., Ledyard, 1995 and references therein).

[4]Since the game exemplifies choices between categorical variables (e.g., products, technologies, etc.) we prefer not to use the term 'effort' to refer to strategies in the game.

[5]The average hourly wage on campus is approximately equal to 8 euros

[6]Instructions are available in the Appendix.

[7]We define 'almost convergence' in this context as the outcome in which five or six players out of seven pick the same action (see Blume and Ortmann, 2000).

[8]In fact, always playing the secure action assures only 14% of achievable earnings to a player.

[9]Strictly speaking, players who picked 1 could earn a positive payoff regardless of coordination with other players. However, since the minimum number was chosen only 25 times out of 1470, we treated these choices as all other positive-payoff choices.

[10]We applied a robust rank-order test (see Siegel and Castellan, 1988) instead of the standard Wilcoxon-Mann-Whitney test to detect differences between the Critical Mass and Increasing Returns distributions because the latter requires that the two samples come from distributions having the same second or higher-order moments, assumption which we have no reason to make in this case. Besides, the robust rank-order test performs better than the Wilcoxon-Mann-Whitney test when sample sizes are ≤ 12, as in our case. For comparisons between distributions in successful and unsuccessful groups, we report the results of the standard Wilcoxon-Mann-Whitney test, which is more appropriate given that the sample sizes in this case are ≥ 12 but not large enough as to render the normal approximation of the robust rank-order test a good one. Both tests, however, were computed and gave identical results. In all tests performed we used group level data as our independent unit of observation (for discussions on differences and similarities between the two tests see Feltovich, 2001).

[11]$p - value = .011$ for the positive-payoff players and $p - value = .000$ for the zero-payoff players, Wilcoxon-Mann-Whitney test.

[12]$p - value = .027$ for the positive-payoff players and $p - value = .001$ for the zero-payoff

players, Wilcoxon-Mann-Whitney test.

[13] $Z = -3.171$, p-value=.002, Wilcoxon Signed Ranks Test.

References

[1] Arthur, B. (1994). *Increasing Returns and Path-Dependence in the Economy*. Ann Arbor, MI: University of Michigan Press.

[2] Battalio, R., Samuelson, L., and Van Huyck, J. (2001). "Optimization Incentives and Coordination Failure in Laboratory Stag Hunt Games". *Econometrica*, 69(3), 749-764.

[3] Berninghaus, S.K., and Ehrhart, K.M. (1998). "Time Horizon and Equilibrium Selection in Tacit Coordination Games: Experimental Results". *Journal of Economic Behavior and Organization*, 37, $231-248$.

[4] Bornstein, G., Gneezy, U., and Nagel, R. (1999). "The effect of intergroup competition on intragroup coordination: An experimental study". Departament d'Economia i Empresa, Universitat Pompeu Fabra working paper. Forthcoming, *Games and Economic Behavior*.

[5] Blume, A., and Ortmann, A. (2000). "The Effects of Costless Pre-play Communication: Experimental Evidence from a Game with Pareto-ranked Equilibria". Charles University Center for Economic Research and Graduate Education working paper.

[6] Camerer, C.F., and Ho, T.H. (1999) "Experience-weighted attraction learning in normal form games". *Econometrica*, 67, 827-874.

[7] Camerer, C.F., and Ho, T.H. (2000). "Sophisticated EWA Learning and Strategic Teaching in Repeated Games". Division of Humanities and Social Sciences, California Institute of Technology, mimeo. Forthcoming, *Journal of Economic Theory*.

[8] Clark, K., and Sefton, M. (2001). "Repetition and signalling: experimental evidence from games with efficient equilibria". *Economics Letters*, 70, 357-362.

[9] Cooper, R. (1999). *Coordination Games*. Cambridge: Cambridge University Press.

[10] Crawford, V. (1991). "An "Evolutionary" Interpretation of Van Huyck, Battalio, and Beil's Experimental Results on Coordination". *Games and Economic Behavior*, 3(1), 25-60.

[11] David, P., and Greenstein, S. (1992). "The Economics of Compatibility Standard: An Introduction to Recent Research". *Economics of Innovation and New Technologies*, 1, $3-41$.

[12] Duffy, J., and Feltovich, N. (1999). "Does Observation of Others Affect Learning in Strategic Environments? An Experimental Study". *International Journal of Game Theory*, 28, 131-152.

[13] Duffy, J., and Feltovich, N. (2000). "Do Actions Speak Louder Than Words? An Experimental Analysis of Observation and Cheap Talk". Forthcoming, *Games and Economic Behavior*.

[14] Duffy, J., and Hopkins, (2001). "Learning, Information and Sorting in Market Entry Games: Theory and Evidence". Department of Economics, University of Pittsburgh working paper.

[15] Erev, I., and Rapoport, A. (1998). "Coordination, "Magic" and Reinforcement Learning in a Market Entry Games". *Games and Economic Behavior*, 23(2), 146-175.

[16] Erev, I., and Roth, A.E. (1998). “Predicting how people play games: reinforcement learning in experimental games with unique, mixed strategy equilibria”. *American Economic Review*, 88, 848-881.

[17] Farrel, J., and Saloner, G. (1986). “Installed Base and Compatibility: Innovation, Product Preannouncements and Predation”. *American Economic Review*, 76, $940-855$.

[18] Feltovich, N. (2001). “Non Parametric Tests of Differences in Medians: Comparisons of the Wilcoxon-Mann-Whitney and Robust Rank-Order Tests”. Department of Economics, University of Houston working paper.

[19] Fudenberg, D., and Levine, D. (1998). *The Theory of Learning in Games*. Cambridge, MA: MIT Press.

[20] Goeree, J.K., and Holt, C.H. (1999). “An Experimental Study of Costly Coordination”. University of Virginia, Department of Economics working paper.

[21] Goeree, J.K., and Holt, C.H. (2001). “Ten Little Treasures of Game Theory and Ten Intuitive Contradictions”. *American Economic Review*, 91(5), 1402-1422.

[22] Granovetter, M., and Soong, R. (1986). “Threshold Models of Interpersonal Effects in Consumer Demand”. *Journal of Economic Behavior and Organization*, 7, $83-99$.

[23] Katz, M., and Shapiro, C. (1986). “Technology Adoption in the Presence of Network Externalities”. *Journal of Political Economy*, 94, $823-841$.

[24] Keser, C., Ehrhart, K.M., and Berninghaus, S.K. (1998). “Coordination and Local Interaction: Experimental Evidence”. *Economics Letters*, 58, 269-275.

[25] Ledyard, J. (1995). “Public Goods: A Survey of Experimental Research”, in A. Roth, J. Kagel, (Eds.). *The Handbook of Experimental Economics*. Princeton: Princeton University Press. $111-194$.

[26] Mitzekewitz, M. and Nagel, R. (1993). “Envy, Greed, and Anticipation in Ultimatum Games with Incomplete Information: An Experimental Study”. *International Journal of Game Theory*, 28, 171-198.

[27] Nagel, R. (1995). “Unraveling in Guessing Games: An Experimental Study”. *American Economic Review* 85, 1013-8026.

[28] Schelling, T. (1960). *The Strategy Of Conflict*. Cambridge, MA: Harvard University Press.

[29] Schelling, T. (1978). *Micromotives and macrobehavior*. New York: E.W. Norton.

[30] Selten, R., and Stoecker, R. (1986). “End behavior in sequences of finite prisoner’s dilemma supergames: A learning theory approach”. *Journal of Economic Behavior and Organization*, 7, 47-00.

[31] Siegel, S., and Castellan, Jr. (1988), *Nonparametric Statistics for the Behavioral Sciences*. New York: Mc-Graw-Hill.

[32] Van Huyck, J., Battalio, R., and Beil, R. (1990). "Tacit Cooperation Games, Strategic Uncertainty, and Coordination Failure". *American Economic Review*, 80, 234 − 248.

[33] Van Huyck, J., Battalio, R., and Beil, R. (1991). "Strategic Uncertainty, Equilibrium Selection, and Coordination Failure in Average Opinion Games". *Quarterly Journal of Economics*, 106, 885 − 910.

[34] Van Huyck, J., Battalio, R., and Beil, R. (1993). "Asset Markets as an Equilibrium Selection Mechanism: Coordination Failure, Game Form Auctions, and Forward Induction". *Games and Economic Behavior*, 5(3), 485-504.

[35] Van Huyck, J., Battalio, R., and Rankin, F. (2001). "Evidence on Learning in Coordination Games". Texas A&M University laser script.

Number I choose:	Number of players who choose number:						
	1	2	3	4	5	6	7
1	1	1	1	1	1	1	1
2	0	2	2	2	2	2	2
3	0	0	3	3	3	3	3
4	0	0	0	4	4	4	4
5	0	0	0	0	5	5	5
6	0	0	0	0	0	6	6
7	0	0	0	0	0	0	7

Table 1: payoff table for payoff function 1, for $N = 7$ players

Number I choose:	Number of players who choose number:						
	1	2	3	4	5	6	7
1	1	2	3	4	5	6	7
2	0	3	4	5	6	7	8
3	0	0	5	6	7	8	9
4	0	0	0	7	8	9	10
5	0	0	0	0	9	10	11
6	0	0	0	0	0	11	12
7	0	0	0	0	0	0	13

Table 2: payoff table for payoff function 2, for $N = 7$ players

Game	information treatment	N. of periods	N. of cohorts
CM	FULL	14	12
IR	FULL	14	12
CM	PAYOFF	14	5
CM	MEDIAN	14	5

Table 3: The different information treatments

Choice distributions				
treatments	CM full info	CM payoff	CM median	IR full info
mean	4.08	4.54	4.37	4.82
st. dev.	1.93	1.99	1.78	2.01
1	10.7	2.9	2.9	4.8
2	7.1	11.4	2.9	6
3	25	25.7	37.1	23.8
4	23.8	17.1	22.9	15.5
5	9.5	8.6	5.7	8.3
6	1.2	0	2.9	1.2
7	22.6	34.3	25.7	40.5
Tot.	100	100	100	100

Table 4: First period choice distributions (in percentages) by treatment, all sessions pooled

Modal choices CM full information treatment														
cohort	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	**3**	**3**	**3**	**3**	**3**	**4***	**4**	**4**	**4**	**4***	**4***	**4***	**4***	**4***
2	3	3	3	3	3	**3**	**4**	**4**	**5***	**6**	**7***	7	7	**7***
3	**1**	**2**	**2**	**3**	**4**	**4**	**4**	**4**	**4**	**4**	**4***	**4***	**4***	**4***
4	3	3	**3**	**3**	**3**	4	**4**	**4**	**5**	**5**	**6**	6	7	**7***
5	7	**3**	**3**	**3**	**3**	**3**	**4**	**4**	**5**	6	7	**7***	**7***	**7***
6	3	7	7	7	7	**7***	**7***	**7***	**7***	**7***	**7***	**7***	**7***	**7***
7	3	**3**	**3**	**4**	5	**5**	6	6	**6***	7	**7***	**7***	**7***	**7***
8	**2**	7	7	7	7	7	**2**	**2**	**2**	**2**	**2**	**3**	**3**	**3**
9	4	4	**4**	**4**	**4**	**4**	**4**	7	**7***	**7***	**7***	**7***	**7***	**7***
10	4	**3**	**2**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**
11	4	4	4	**3**	**3**	**3**	**3**	**3**	**3**	**4**	**4**	**4**	**4***	**4***
12	3	5	5	5	5	**5**	**5**	**5**	**5**	5	7	**7***	**7***	**7***

Modal choices IR full information treatment														
cohort	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	7	7	7	**7***	**7***	7	**7***	**7***	**7***	**7***	**7***	**7***	**7***	**7***
2	1	4	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**4***	**4**	**4***	**4***	**4***
3	**3**	4	**7***	**7***	**7***	**7***	**7***	**7***	**7***	**7***	**7***	**7***	**7***	**7***
4	**4**	**5**	**6**	7	**7***	**7***	**7***	**7***	**7***	**7***	**7***	**7***	**7***	**7***
5	5	5	**5**	**5**	**5**	6	6	**6***	6	7	**7***	**7***	**7***	**7***
6	4	7	7	7	7	**7***	7	**7***	**7***	**7***	**7***	**7***	**7***	**7***
7	**3**	**3**	**3**	**3**	**3**	5	5	5	**5**	**5**	**5**	5	5	6
8	**3**	**4**	4	5	**5**	**5**	**5**	**5**	**5**	**5***	**5***	**5***	**5***	**5***
9	3	5	**5**	**5**	**5**	7	**7***	**7***	**7***	**7***	**7***	**7***	**7***	**7***
10	7	7	7	**7***	**7***	**7***	**7***	**7***	**7***	**7***	**7***	**7***	**7***	**7***
11	7	7	**7***	**7***	**7***	7	**7***	**7***	**7***	**7***	**7***	**7***	**7***	**7***
12	7	7	**7***	7	**7***	**7***	**7***	**7***	**7***	**7***	**7***	**7***	**7***	**7***

Table 5: Modal choices per period, CM and IR games with full information, 24 cohorts (in case of multiple modes, only the smaller mode is reported). Numbers in bold indicate that the threshold associated to that number was matched. A star indicates a mutual best response outcome.

	Modal choices CM payoff treatment													
cohort	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	7	7	7	7	7	7	**1**	**2**	**3**	**3**	**3**	4	**3**	**3**
2	**3**	7	4	**3**	3	7	**3**	**3**	3	**3**	3	**3**	**3**	**3**
3	**3**	**2**	**3**	**3**	**3**	**3**	**2**	**3**	**2**	**3**	**3**	**3**	**3**	**3**
4	5	7	3	**3**	**2**	4	**3**	**3**	**3**	**3**	5	**3**	**3**	**3**
5	2	**3**	4	**3**	**3**	4	4	7	7	**3**	4	**3**	**3**	**3**

Table 6: Modal choices per period, CM payoff treatment, 5 cohorts (In case of multiple modes, only the smaller mode is reported). Numbers in bold indicate that the threshold associated to that number was matched. A star indicates a mutual best response outcome.

	Modal choices CM median treatment													
cohort	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	3	7 (4)	4 (5)	3 (5)	7 (4)	3 (4)	**2** (3)	**3** (4)	**4** (3)	5 (4)	**3** (5)	**3** (5)	**3** (4)	**3** (3)
2	7	7 (7)	7 (7)	**3** (7)	**3** (3)	**3** (3)	**3** (3)	**3** (3)	**3** (3)	**3** (3)	**3*** (3)	**3** (3)	**3*** (3)	**3*** (3)
3	**4**	4 (4)	**4** (4)	**4** (4)	**4** (4)	**4** (4)	**4*** (4)	**4** (4)	**4** (4)	**4*** (4)	**4*** (4)	**4*** (4)	**4*** (4)	**4** (4)
4	**3**	**3** (3)	**3** (4)	**3** (4)	**3** (3)	**3** (3)	**3** (3)	**3** (3)	**3** (3)	**3*** (3)	**3*** (3)	**3*** (3)	**3** (3)	**3*** (3)
5	**3**	**4** (3)	**2** (4)	**4** (3)	**4** (4)	**4** (4)	**4** (4)	**4** (4)	**4*** (4)	**4** (4)	**4** (4)	**4** (4)	**4** (4)	**4*** (4)

Table 7: Modal choices per period, CM median treatment, 5 cohorts. Numbers in parentheses indicate the value of the previous period group median.

		CM (n=12)	IR (n=12)
SUCC.	pos. payoff pl.	53%	57%
($n = 16$)	zero payoff pl.	81%	97%
	$n = 7$ pos. payoff pl.	22%	35%
	$n = 7$ zero payoff pl.	40%	71%
UNSUCC.	pos. payoff pl.	26%	20%
($n = 8$)	zero payoff pl.	59%	66%
	$n = 7$ pos. payoff pl.	4%	4%
	$n = 7$ zero payoff pl.	18%	14%

Table 8: Percentages of positive and zero payoff players that conform to rule 1 and 2 with strict inequality, and percentages of positive and zero payoff players that pick action 7, separately for the CM and IR games and for successful and unsuccessful cohorts. All percentages are computed as averages across groups.