COORDINATION SUCCESS IN NON-COOPERATIVE LARGE GROUP MARKET ENTRY GAMES

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When several firms independently consider entry into a new market, tacit coordination becomes critical for solving the problem of multiple equilibria. Several recent studies (Kahneman, 1988; Erev and Rapoport, 1998; Rapoport, 1995; Rapoport et al., 1998; Rapoport, Seale, and Winter, 1997; Sundali, Rapoport, and Seale, 1995) have shown that tacit coordination in a class of non-cooperative market entry games with a large number of agents is accounted for remarkably well by the Nash equilibrium solution. To Kahneman, who first introduced this game, the behavioral regularities found in the game looked "like magic" (1988, p. 12). Subsequent experimental studies of the market entry game by Rapoport and his associates, which systematically manipulated the information structure of the game, compared behavior in the domains of gains and losses, or introduced private information and asymmetry between players, have shown that this "magic" is robust. Under a wide variety of experimental conditions, interacting players in large groups playing the market entry game with no communication among them rapidly achieve coordination success that is accounted for on the aggregate level by a Pareto deficient equilibrium solution.

1. The Market Entry Game

To study tacit coordination, we devised a class of iterated market entry games (Selten and Güth, 1982) played by a group N for T periods (trials), where the values of $n = |N|$ and T are common knowledge. At the beginning of each period (stage game) t, $t = 1, \ldots, T$, a possibly different positive integer c $(1 \leqslant c \leqslant n)$, interpreted as the "known capacity of the market," is publicly announced. Each player i $(I \in N)$ is then privately informed of her entry fee h_i $(h_i \geqslant 0)$ for that period. After the value of c becomes common knowledge, each player i must decide privately and anonymously whether to enter the market $(d_i = 1)$ or stay out of it $(d_i = 0)$. Communication before or during the game is prohibited. Individual payoffs for each period are determined by

$$H_i(\mathbf{d}) = \begin{cases} v, & \text{if } d_i = 0, \\ k + r(c - m) - h_i, & \text{if } d_i = 1, \end{cases}$$

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where v, k, and r are real-valued, commonly known constants that remain fixed across iterations, m $(0 \leqslant m \leqslant n)$ is the actual number of entrants for that period, and $\boldsymbol{d} = (d_1, d_2, \dots, d_n)$ is the vector of n (binary) decisions. At the end of each period, players may or may not be informed of the value of m and, consequently, their individual payoff for that period. Information about the decisions and payoffs of other members of the group is not disclosed.

When $h_i = 0$ for all $I \in N$ (Erev and Rapoport, 1998; Rapoport, 1995; Rapoport et al., 1998; Sundali, Rapoport, and Seale, 1995), the resulting game is characterized by symmetric players, complete information, and zero entry fees in which the incentive to enter the market decreases linearly with the number of entrants. When the entry fee is private information, and only the distribution of entry fees in the population is known (Rapoport, Seale, and Winter, 1997), the effects of asymmetry between players can be studied. Whether players are symmetric or not, each player is faced on each period with a binary choice between earning a fixed payoff, regardless of the actions taken by the other players, or an uncertain payoff which is a linear function of the difference cm.

2. Results

2.1. *Sundali, Rapoport, and Seale (1995)*

Sundali, Rapoport, and Seale (1995), conducted two different computer-controlled experiments. In both experiments the value of c in each period was chosen randomly and without replacement from the set of market capacities $C = \{1, 3, \dots, 19\}$. This determined a block of ten trials. The same procedure was then repeated, with a different random selection of market capacities, for six blocks in Experiment 1 $(T = 60)$ and ten blocks in Experiment 2 $(T = 100)$. The parameter values for Experiment 1 were $v = k = 1$, $r = 2$, $n = 20$, and $h_i = 0$ for all $i \in N$. What characterizes Experiment 1 is that no information about the number of entrants, m, and the individual payoff, $H_i(\boldsymbol{d})$, was given at the end of each trial to prevent learning. Table 1 presents the number of entries by block of ten trials and market capacity values across the twenty subjects. The values of c are presented in an ascending order, not in the random order of their presentation, which differed from block to block. The correlations between c and m for each block separately, and across the six blocks, are shown in the bottom row of the table. The means and standard deviations of number of entries across blocks, computed for each value of c separately, are presented in the two right-hand columns of the table.

For the market entry game played in Experiment 1, there are $r!/c!(n-c)!$ pure strategy equilibria in which $m^*(c) = c$ players enter and $n!/(c-1)!(n-c+1)!$ pure strategy equilibria in which $m^*(c) = c - 1$ players enter. There is also a symmetric mixed-strategy equilibrium in which, given c and assuming players to be risk-neutral, each player enters with probability $(c-1)/(n-1)$. Although no trial-to-trial feedback was provided, the aggregate results in Table 1 are accounted for surprisingly well by the equilibrium solutions. First, there is a positive and highly significant correlation

Table 1
Reports the number of entries by market capacity across the six blocks of trials for Experiment 1 of Sundali, Rapoport, and Seale (1995), where subjects made entry decisions without feedback. The correlation between the number of entries and market capacity is shown in the last row of the table. The shaded cells indicate those trials where the number of entries was within ±1 of the pure strategy equilibrium prediction

Capacity	Prediction	Block of ten trials						Total	Mean	SD
		1	2	3	4	5	6			
1	[0, 1]	1	0	0	1	0	0	2	0.33	0.47
3	[2, 3]	4	4	4	5	4	3	24	4.00	0.58
5	[4, 5]	7	7	6	6	7	7	40	6.67	0.47
7	[6, 7]	11	11	10	12	11	8	63	10.50	1.26
9	[8, 9]	13	10	11	12	9	13	68	11.33	1.49
11	[10, 11]	9	8	8	11	11	7	54	9.00	1.53
13	[12, 13]	15	12	11	11	9	12	70	11.67	1.80
15	[14, 15]	15	16	14	14	12	11	82	13.67	1.70
17	[16, 17]	15	16	14	14	16	17	92	14.83	0.90
19	[18, 19]	17	18	18	18	19	17	107	17.83	0.69
Total		107	102	96	104	98	95	602		
Correlation		0.93	0.94	0.94	0.92	0.93	0.91	0.92		

Key findings: (1) Positive and highly significant correlations between the number of entries m and market capacity c, (2) mean number of entries is accounted for by the pure strategy equilibrium prediction, (3) 62% (37 out of 60) of the trials are within ± of the equilibrium prediction.

between c and m. In equilibrium this correlation is 1, whereas in actuality it ranged between 0.91 and 0.94, accounting for approximately 85% of the variance. Second, the mean number of entries is well approximated by the equilibrium solution. We used the measure $d(c) = |m^*(c) - m(c)|$ to assess the goodness of fit, and found $d(c) = 0$ for 22 out of the 60 trials, $d(c) = 1$ for 15 trials, and $d(c) = 2$ for 12 more trials. $d(c) > 2$ in only 18% of all trials.

On the individual level, we find considerable differences between players. Table 2 shows the number of entries, summed across the six blocks of ten periods each, by subject and value of c. The total number of entries (out of a maximum of 60), shown in the bottom row of Table 2, varies considerably from 5 (Subject 10) to 52 (Subject 16), and the individual profiles support in general neither a mixed-strategy equilibrium nor cutoff decision rules of the type "enter if and only if $c \geqslant c^*$," where c^* is some cutoff value constant across blocks.

Table 2

The table reports the total number of entries by market capacity for each of the twenty subjects in Experiment 1 of Sundali, Rapoport, and Seale (1995). Subjects are arranged by the index s. This index is a measure of decision consistency, where $0 \leqslant s \leqslant 30$, and takes its largest value when subjects approach a cutoff-type decision rule

Capacity	Subject																			
	S08	S04	S16	S06	S05	S10	S12	S17	S14	S20	S11	S03	S18	S07	S15	S13	S19	S01	S09	S02
1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0
3	0	0	4	0	0	0	6	1	1	1	0	0	6	0	0	0	1	0	1	3
5	0	0	6	0	0	0	0	6	0	4	1	0	6	1	4	1	4	1	1	5
7	6	0	6	0	0	0	6	6	0	4	2	0	6	4	5	2	5	4	3	4
9	6	0	6	2	1	0	6	4	0	5	5	3	5	4	6	3	4	3	1	4
11	6	0	6	6	1	1	1	0	2	5	3	2	1	3	4	2	4	2	2	3
13	6	1	6	6	6	0	0	3	3	6	6	3	2	1	4	2	5	4	2	4
15	6	6	6	6	6	0	6	6	6	6	6	6	2	1	1	2	2	3	3	2
17	6	6	6	6	6	0	2	6	6	6	6	6	4	6	3	3	4	4	3	3
19	6	6	6	6	6	4	5	6	6	6	6	6	4	6	3	6	4	5	5	5
Total	42	19	52	32	26	5	33	38	24	43	35	26	36	26	30	21	34	26	21	33
s Index	30	29	28	28	28	27	25	24	24	23	23	22	20	20	16	15	14	14	13	11

Key findings: (1) Substantial individual differences in the total number of entry decisions and propensity to enter, given various market capacities, (2) individual decision profiles support neither a mixed strategy equilibrium nor rules of the type "enter only if $c \geqslant c^*$, where c^* is some cutoff value constant throughout the experiment.

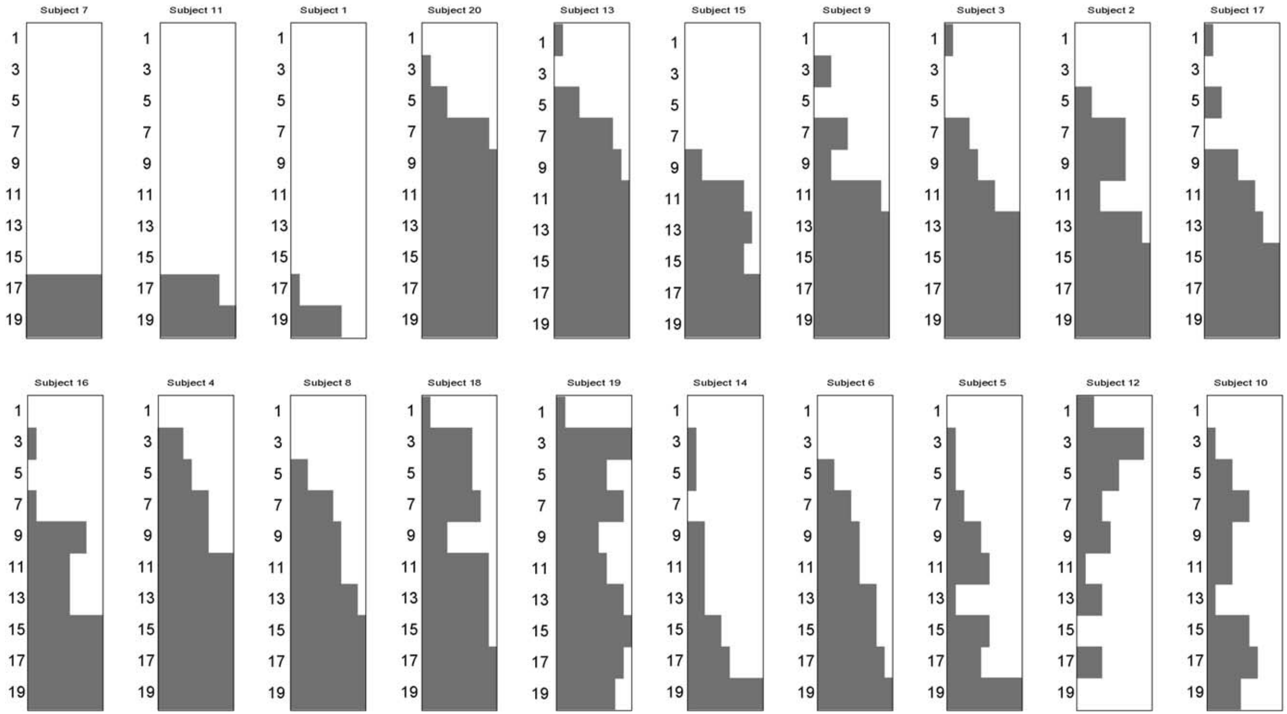
Table 3
Reports the aggregate number of entries by market capacity across the ten blocks of trials for the three twenty-subject groups of Experiment 2 of Sundali, Rapoport, and Seale (1995), where subjects made entry decisions with trial-to-trial feedback. The correlation between the number of entries and capacity is shown in the last row of the table

Capacity	Prediction	Block of ten trials										Total	Mean	SD
		1	2	3	4	5	6	7	8	9	10			
1	[0, 1]	4	2	4	4	1	2	6	3	4	1	31	1.03	1.60
3	[2, 3]	17	12	9	9	7	12	11	11	10	12	110	3.67	2.67
5	[4, 5]	29	15	12	17	13	18	13	14	11	12	154	5.13	5.27
7	[6, 7]	20	21	26	21	18	23	23	25	21	25	223	7.43	2.54
9	[8, 9]	11	34	30	31	27	23	25	27	28	24	260	8.67	6.24
11	[10, 11]	42	34	28	33	32	36	30	29	40	31	335	11.17	4.62
13	[12, 13]	34	35	41	41	34	32	39	38	32	37	363	12.10	3.40
15	[14, 15]	34	45	42	38	49	45	45	40	43	43	424	14.13	4.22
17	[16, 17]	48	50	48	48	50	53	46	50	51	50	494	16.47	1.96
19	[18, 19]	54	55	56	55	56	53	54	54	54	55	546	18.20	0.97
Total		293	303	296	297	287	297	292	291	294	290	294		
Correlation		0.86	0.99	0.99	0.99	0.99	0.98	0.99	0.99	0.98	0.99	0		

Key findings: (1) The differences between the mean number of entries and the equilibrium prediction are very small, and (2) with the exception of the first block, the correlations between the number of entries and capacity are equal to or higher than 0.98.

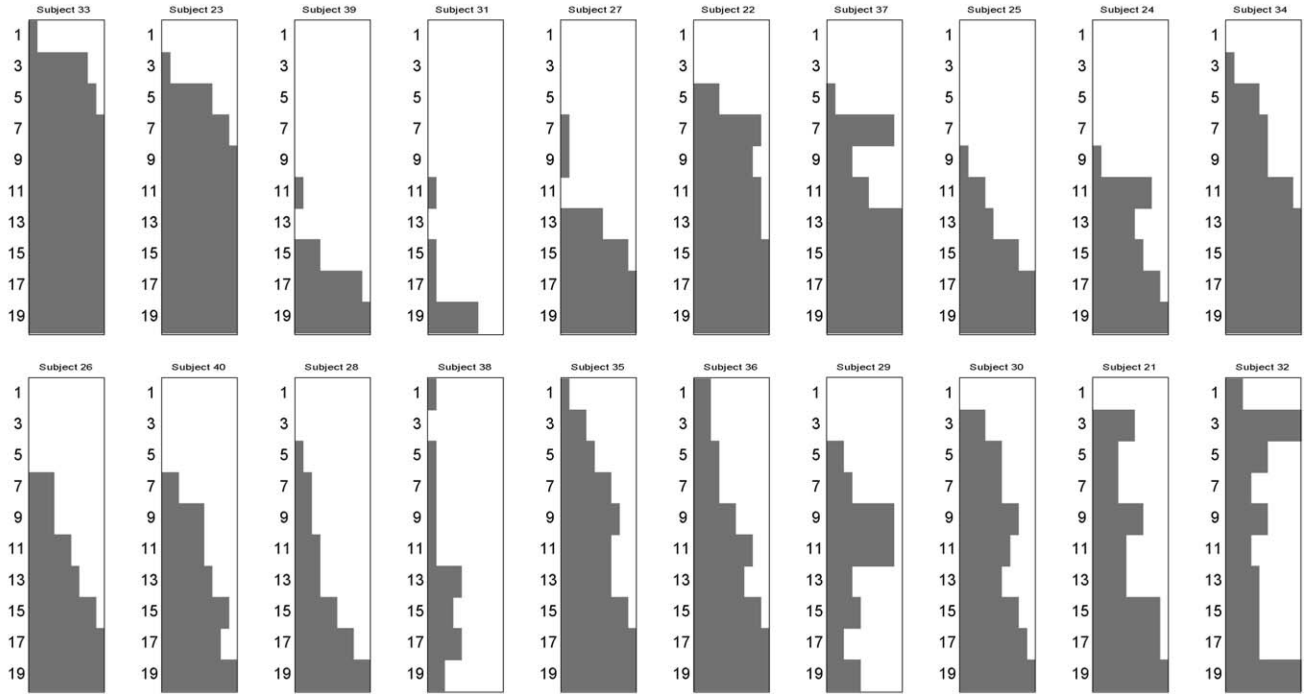
Experiment 2 of Sundali, Rapoport, and Seale (1995) introduced three major changes. First and most importantly, trial-to-trial feedback about the number of entrants (m) and individual payoff ($H_i(\boldsymbol{d})$) was given, thereby allowing for learning. Second, the value of T was increased from 60 to 100. Third, the subjects were allowed to keep track of the history of the game. Three different groups, each including $n = 20$ subjects, were recruited. Table 3, which uses the same format as Table 1, shows the number of entries by block and market capacity across the sixty subjects. Basically, Table 3 shows the same aggregate results as Table 1: the differences between the mean number of entries and the value of c are very small, and the correlations between c and m are equal to or greater than 0.98 (except of Block 1).

Figures 1a, 1b, and 1c display the individual number of entries for each subject in Groups 1, 2, and 3, respectively. The decisions of each subject in Blocks 2 to 10 (Block 1 is omitted) are displayed by a rectangular bar, called a profile. The horizontal axis of each bar is divided into nine equal intervals (not shown in the figure), and the vertical axis shows the ten values of c ordered from 1 to 19. The total number of entries can take any integer from 0 to 90. (For example, Subject 1 in Group 1 only entered once on $c = 17$ and six times on $c = 19$ for a total of seven entries.) Within each group, the twenty subjects are ordered in terms of an index $s = \sum |4.5 - v|$, $v = 0, 1, \ldots, 9$, which assumes its maximum value when each of the ten rows of the profile includes either 0's or 1's. The profiles in Figures 1a, 1b, and 1c display the individual differences



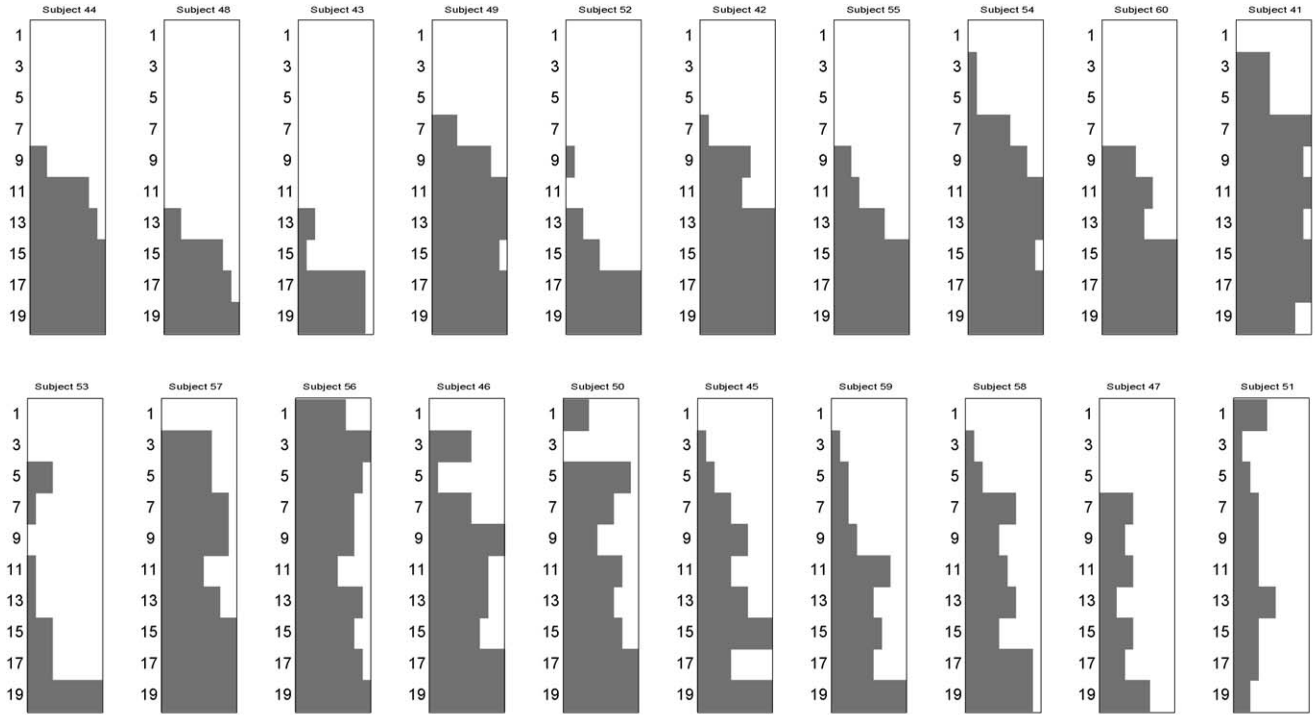
Key findings: (1) Substantial individual differences in entry rules, and (2) no evidence that the majority of subjects use a cutoff-type rule, or mix their decisions as prescribed by the mixed strategy equilibrium solution.

Figure 1a. Displays the number of entries by market capacity for each subject in Group 1 of Sundali, Rapoport, and Seale (1995). These individual profiles are arranged by the index s (not shown), a measure of decision consistency.



Key findings: (1) Substantial individual differences in entry rules, and (2) no evidence that the majority of subjects use a cutoff-type rule, or mix their decisions as prescribed by the mixed strategy equilibrium solution.

Figure 1b. Displays the number of entries by market capacity for each subject in Group 2 of Sundali, Rapoport, and Seale (1995). These individual profiles are arranged by the index s (not shown), a measure of decision consistency.



Key findings: (1) Substantial individual differences in entry rules, and (2) no evidence that the majority of subjects use a cutoff-type rule, or mix their decisions as prescribed by the mixed strategy equilibrium solution.

Figure 1c. Displays the number of entries by market capacity for each subject in Group 3 of Sundali, Rapoport, and Seale (1995). These individual profiles are arranged by the index *s* (not shown), a measure of decision consistency.

in the total number of entries and in the degree of consistency of decisions with a fixed cutoff decision rule across blocks. Clearly, different subjects in each group use different decision rules (with much switching in decision between adjacent blocks for the same value of c), but on the aggregate level the results are orderly and very close to the Nash equilibrium solution.

2.2. Rapoport et al. (1998)

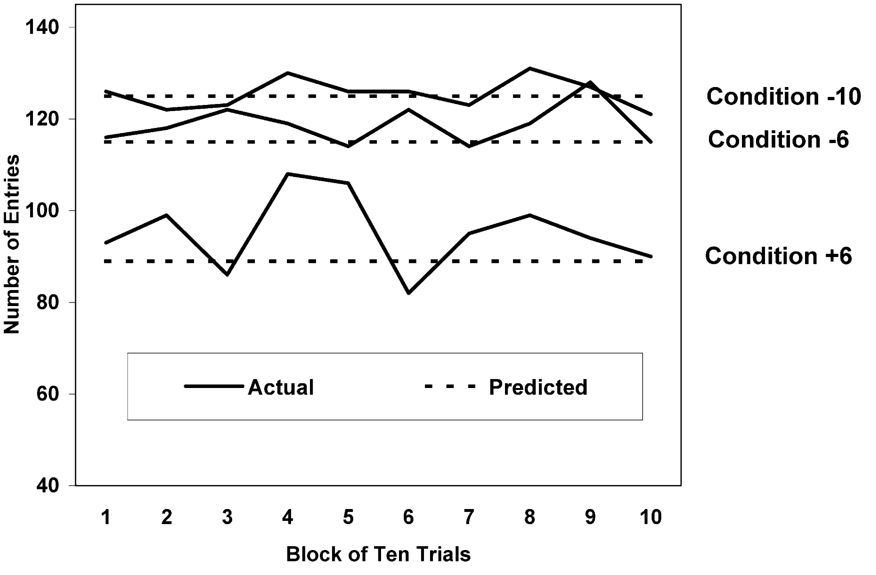
Using the same experimental design as Sundali, Rapoport, and Seale (1995), Rapoport et al. (1998), extended the investigation to the case $v \neq k$. In particular, they focused on two cases: in the first case $v < 0 < k$, and in the second $v > k > 0$. In the former case, each player faces a choice between staying out and losing a certain amount v with certainty or entering the market and earning an uncertain payoff that is likely to be negative because of excessive entry. In the latter case, the tension is between receiving a positive payoff v with certainty and receiving an uncertain payoff that is likely to be positive because of too few entrants. Phenomenologically, the difference between these two domains of losses and gains is considerable (see Kahneman and Tversky, 1979).

Rapoport et al. (1998) included three conditions in a between-subjects design. In all three conditions $k = 1$, $r = 2$, and $n = 20$. The "staying out" parameter v assumed the values 6, -6, and -10, for Conditions 1, 2, and 3, respectively. Initial endowments were $-$\$69.9, \$110.1, and \$170.0, for Conditions 1, 2, and 3, respectively. They were set in such a way that if a subject stayed out on all 100 trials, her payoff would have been \$20.1. As before, ten different values of c were presented randomly in each of ten blocks of trials ($T = 100$).

The pure strategy asymmetric equilibria specify $c - 3$, $c + 3$, and $c + 5$ entrants for Conditions 1, 2, and 3, respectively. Clearly, they do not specify which subjects should enter. There exists a symmetric mixed-strategy equilibrium, in which each player enters with probability $[r(c - 1) + k - v]/[r(n - 1)]$. These equilibria are Pareto deficient; players can increase their payoff substantially by entering with a smaller probability.

Figure 2 presents the actual and predicted number of entries summed over the ten values of c by condition and block. The actual number of entries increases from 95.2 in Condition 1 through 118.7 in Condition 2 to 125.5 in Condition 3. In comparison, the predicted number of entries per block are 89, 115, and 125, respectively. The correlations $r_{(c,m)}$, (not shown) are very high (median $= 0.91$) and in agreement with the equilibrium solution. With respect to the fit provided by the equilibrium solution to the aggregate data, we find no difference between the three conditions, or between the results of Rapoport et al. (1998) and those reported earlier in Experiment 2 of Sundali, Rapoport, and Seale (1995).

The three panels of Figure 3 display the mean observed and predicted number of entries for each value of c in Conditions $+6$, -6, and -10, respectively. Note that the ten values of c vary from condition to condition, depending on the value of v. Each panel of Figure 3 shows that, as a first approximation, the Nash equilibrium solution – in either pure or mixed strategies – organizes the total number of entries very well:



Key findings: The predicted number of entries tracks the actual mean number of entries in each condition. Mean entries increase from 95.2 in Condition +6 through 118.7 in Condition −6 to 125.5 in Condition −10. Predicted number of entries are 89, 115 and 125, respectively.

Figure 2. Actual and predicted number of entries for Conditions +6, −6 and −10 in Rapoport et al. (1998).

the observed mean increases linearly in c, and the absolute difference between observed and predicted values is rather small. There is a slight tendency to enter more often than predicted on low values of c and less often than predicted on high values of c.

Figures 4a, 4b, and 4c display the individual profiles for each condition separately. The only difference from the profiles in Figures 1a, 1b, and 1c is that the horizontal axis of each profile is divided now into ten rather than nine equal intervals. Similarly to Figures 1a to 1c, Figures 4a to 4c show that very few subjects used cutoff decision rules consistently across all ten blocks. Indeed, there are many profiles (e.g., Subjects 11 and 16 in Figure 4a) that defy a simple characterization. Similar to the previous study by Sundali, Rapoport, and Seale (1995), the individual results portrayed in Figures 4a to 4c support neither a cutoff decision rule, which remains unaltered across the 100 trials, nor a symmetric mixed-strategy equilibrium in which the probability of entry increases in c. Additional analyses of the data, not reported here, suggest that the remarkable coordination success on the aggregate level is achieved through some sort of adaptive learning.

2.3. *Rapoport, Seale, and Winter (1997)*

In yet another major extension of the basic market entry game, Rapoport, Seale, and Winter (1997), introduced asymmetry between players by charging differential entry

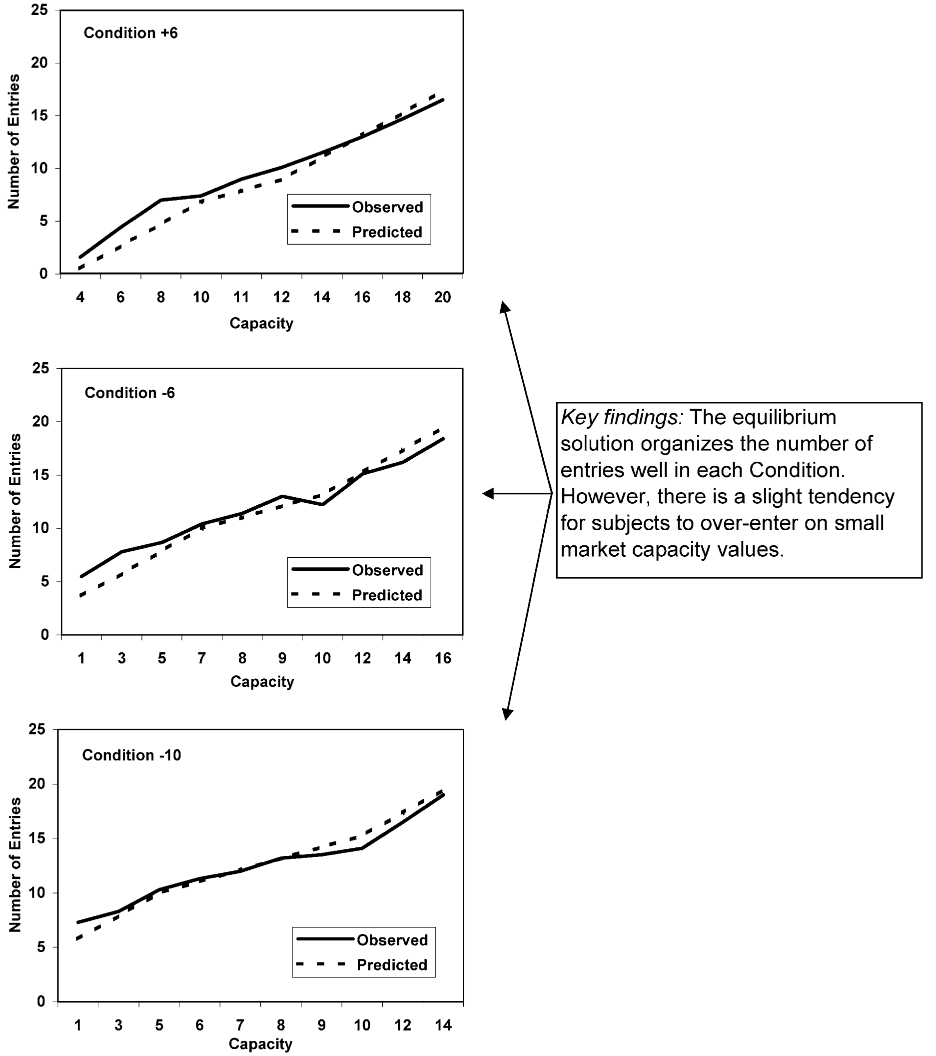
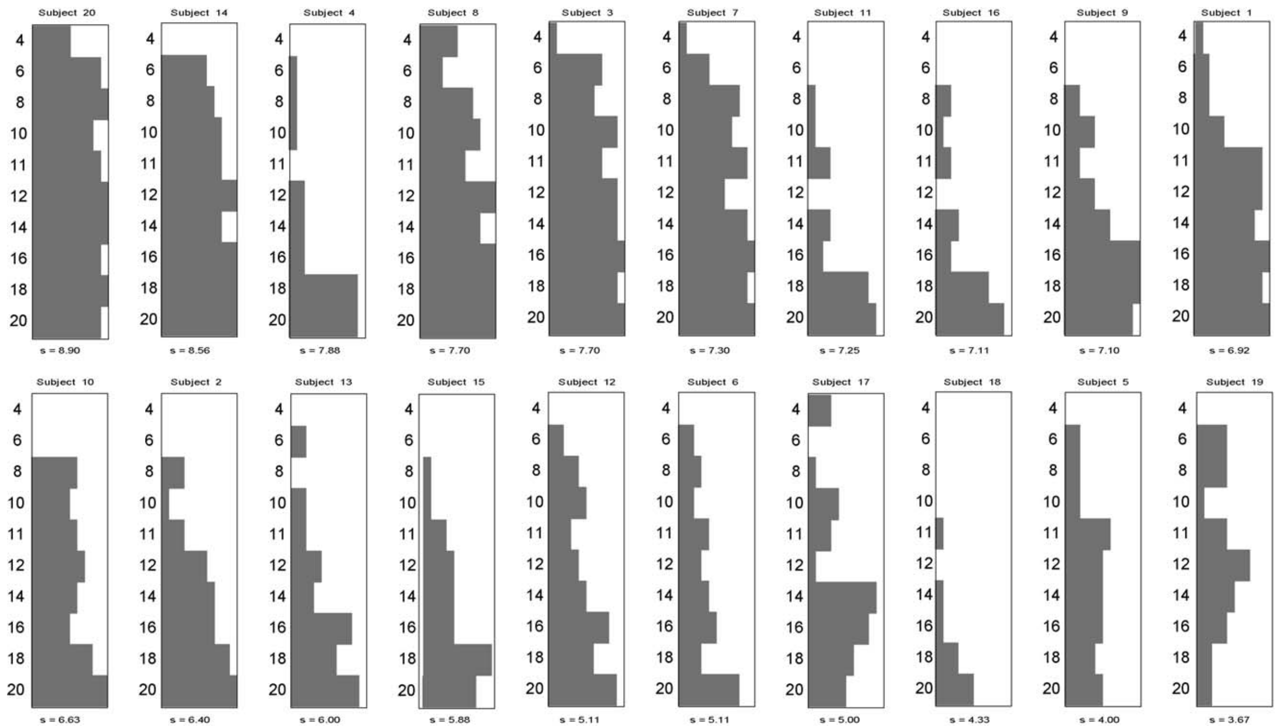


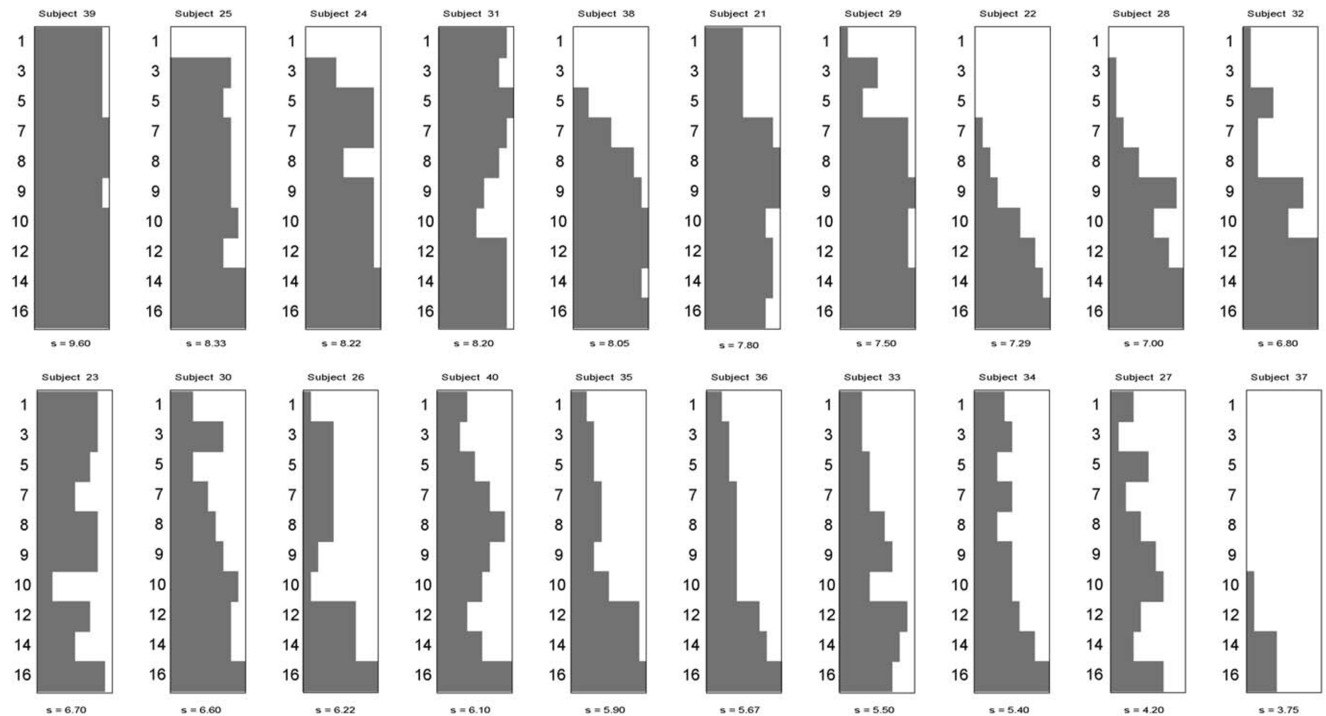
Figure 3. Observed and predicted number of entries by market capacity for Conditions +6, −6, and −10 in Rapoport et al. (1998).

fees. The parameter values were the same as in Experiment 2 of Sundali, Rapoport, and Seale (1995), namely, $v = 1$, $k = 1$, $r = 2$, $T = 100$, and $c \in \{1, 3, \ldots, 19\}$. In addition, the twenty subjects in each group were divided into $J = 5$ types, with four members each, and privately charged entry fees which assumed the values $h_j = 1, 2, 3, 4$, and 5, respectively ($j = 1, 2, \ldots, J$). The distribution of entry fees was common knowledge. Two different groups of $n = 20$ participated in this study. At the



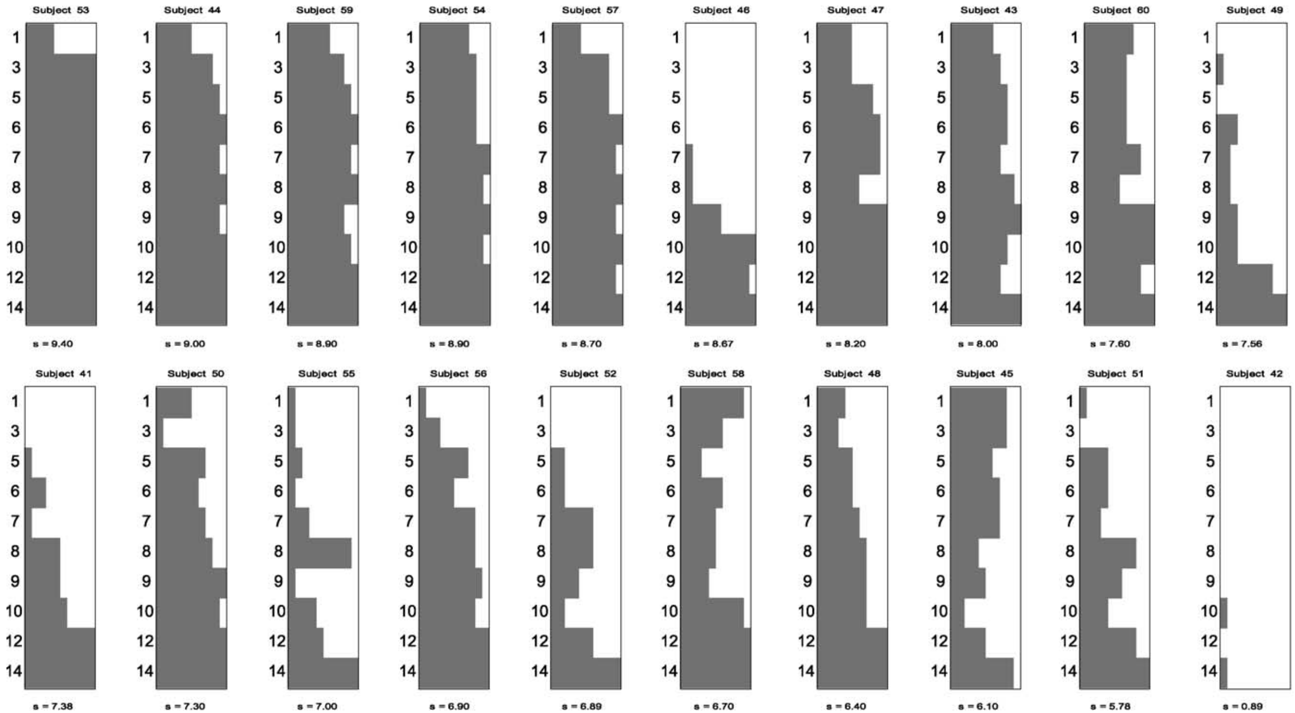
Key findings: (1) Substantial individual differences in entry rules, and (2) no evidence that the majority of subjects use a cutoff-type rule, or mix their decisions as prescribed by the mixed strategy equilibrium solution.

Figure 4a. Displays the number of entries by market capacity for Condition +6 of Rapoport et al. (1998). These individual profiles are arranged by the index s, a measure of decision consistency.



Key findings: (1) Substantial individual differences in entry rules, and (2) no evidence that the majority of subjects use a cutoff-type rule, or mix their decisions as prescribed by the mixed strategy equilibrium solution.

Figure 4b. Displays the number of entries by market capacity for Condition −6 of Rapoport et al. (1998). These individual profiles are arranged by the index s, a measure of decision consistency.



Key findings: (1) Substantial individual differences in entry rules, and (2) no evidence that the majority of subjects use a cutoff-type rule, or mix their decisions as prescribed by the mixed strategy equilibrium solution.

Figure 4c. Displays the number of entries by market capacity for Condition −10 of Rapoport et al. (1998). These individual profiles are arranged by the index s, a measure of decision consistency.

Table 4

Reports the total number of entries by market capacity across the ten blocks of trials for the two groups of Rapoport, Seale, and Winter (1997). The correlation between the number of entries and capacity is shown in the last row of the table. The shaded cells indicate those trials where the number of entries was within ±1 of the equilibrium prediction

Capacity	Prediction	Block of ten trials										Total	Mean	SD
		1	2	3	4	5	6	7	8	9	10			
Group 1														
1	[0]	2	0	0	0	0	1	0	0	0	0	3	0.3	0.67
3	[2]	0	1	2	2	3	4	2	1	2	2	19	1.9	1.10
5	[4]	7	6	2	3	5	3	3	4	5	4	42	4.2	1.55
7	[5, 6]	1	9	3	7	6	7	7	5	4	5	54	5.4	2.32
9	[7, 8]	9	3	11	9	8	7	8	8	7	7	77	7.7	2.06
11	[9]	9	7	16	9	11	8	10	9	10	9	98	9.8	2.44
13	[11]	11	10	10	8	13	11	11	10	12	12	108	10.8	1.40
15	[12, 13]	7	16	15	10	13	12	13	13	15	12	126	12.6	2.63
17	[14, 15]	12	15	12	11	15	15	15	15	14	16	140	14.0	1.70
19	[16]	13	18	14	14	16	16	17	17	17	16	158	15.8	1.62
Total	[80, 84]	71	85	85	73	90	84	86	82	86	83	825		
Correlation		0.86	0.90	0.86	0.95	0.99	0.98	0.99	0.99	0.99	0.99	1.00		

(*continued on next page*)

end of each period, each subject was informed of the total number of entries and her payoff for the period.

When players are not symmetric, there exist no mixed-strategy equilibria which are symmetric within type. There exist multiple pure strategy equilibria, some of which are monotonic (i.e., $m_j^* \geqq m_{j+1}^*$, $j = 1, 2, 3, 4$, where m^* is the equilibrium number of entrants of type j, $0 \leqq m^* \leqq 4$) and some are not. Efficient equilibria are the ones maximizing the group payoff associated with equilibrium play.

Table 4 shows the number of entrants by block and c value for each group separately. Similarly to previous tables, the ten values of c appear in ascending order, not in the actual order of their presentation. The total number of entries across the ten blocks is presented in column 13, the means and standard deviations are shown in columns 14 and 15, and the efficient equilibrium number of entrants (predictions) are presented as the first number in the second column from the left. The difference between the predicted and observed mean number of entries is not significant in 19 of 20 comparisons

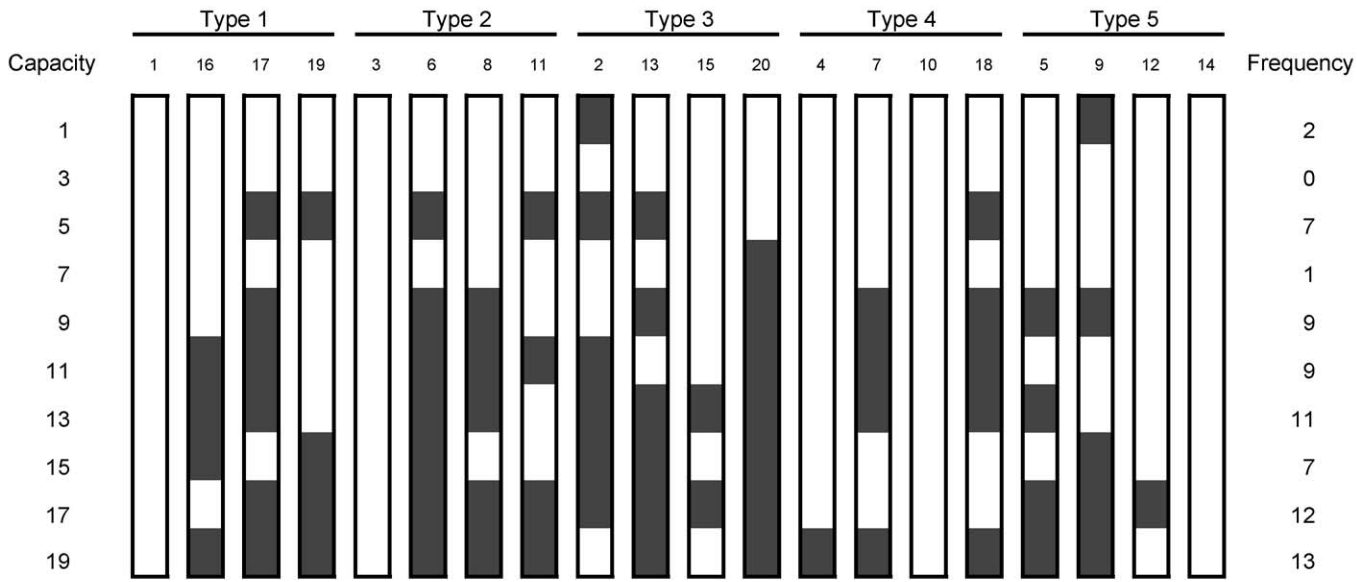
Table 4
(*Continued*)

Capacity	Prediction	Block of ten trials										Total	Mean	SD
		1	2	3	4	5	6	7	8	9	10			
Group 2														
1	[0]	5	1	1	0	1	0	1	0	0	0	9	0.9	1.52
3	[2]	2	4	1	4	2	1	2	3	2	1	22	2.2	1.14
5	[4]	3	4	4	5	4	6	2	3	3	4	38	3.8	1.14
7	[5, 6]	6	7	5	6	8	7	7	9	6	5	66	6.6	1.26
9	[7, 8]	14	8	11	7	6	9	5	6	8	8	82	8.2	2.66
11	[9]	9	12	8	10	8	11	9	8	10	8	93	9.3	1.42
13	[11]	12	11	13	11	12	9	13	10	12	10	113	11.3	1.34
15	[12, 13]	14	15	11	14	13	14	12	15	11	15	134	13.4	1.58
17	[14, 15]	16	14	15	17	13	15	15	13	14	15	147	14.7	1.25
19	[16]	15	17	18	16	16	17	17	15	16	17	164	16.4	0.97
Total	[80, 84]	96	93	87	90	83	89	83	82	82	83	868		
Correlation		0.88	0.98	0.96	0.98	0.97	0.97	0.97	0.94	0.98	0.98	0.99		

Key findings: (1) Positive and highly significant correlations between the number of entries and market capacity that increase over block, (2) mean number of entries is accounted for by the equilibrium prediction, (3) 76% (152 out or 200) of the trials are within ±1 of the equilibrium prediction.

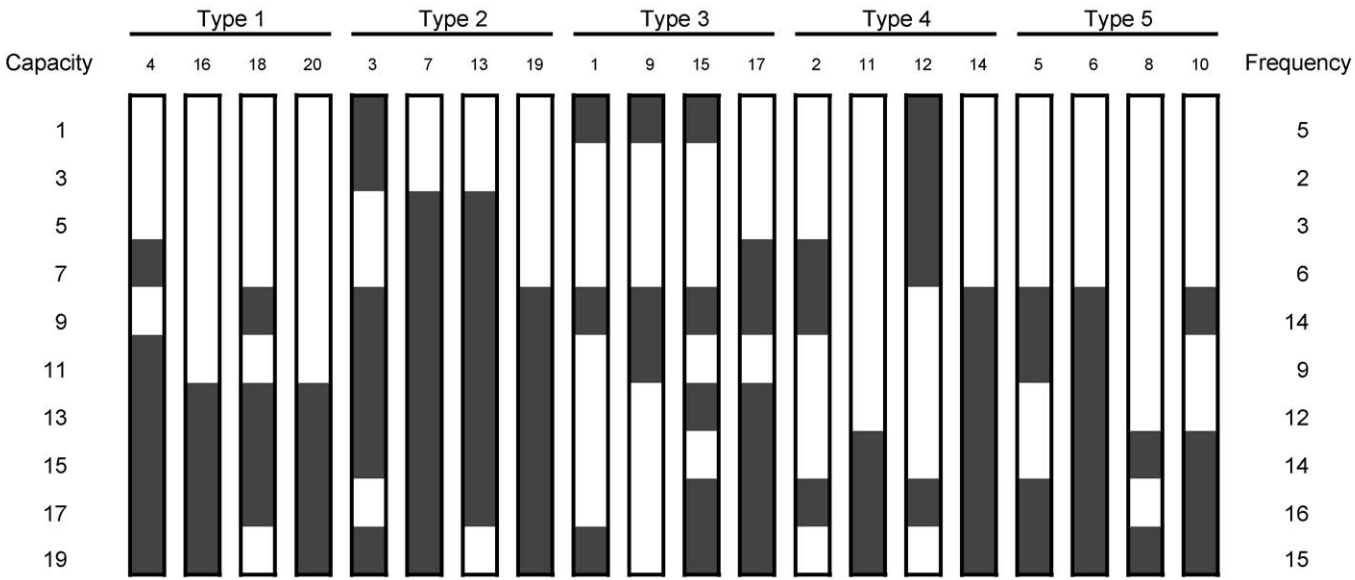
(10 values of c times 2 groups), and the correlations $r_{(c,m)}$ increase across blocks from 0.86 and 0.88 in Block 1 to 0.99 and 0.98 in Block 10. Similarly to all previous studies, we observe remarkable coordination success on the aggregate level – which increases with experience – even in the presence of private information about entry fees and considerable asymmetry between types of players.

However, we do not observe the expected differences between types. Table 5 presents the total number of entries across the ten blocks of trials partitioned into the $J = 5$ types of players. The frequencies are displayed by value of c for each type separately. The results shown in this table reject the equilibrium as an explanatory concept. For example, whether the equilibria are monotonic or not, all four players of type 1 are predicted to always enter if $c \geqq 9$, all four players of type 5 are not expected to enter if $c \leqq 15$, and the total number of entries should decrease in j. All of these predictions are violated. Similarly, examination of the individual profiles and the frequency of switches in decision for the same value of c across adjacent blocks clearly rejects the Nash equilibrium solution.



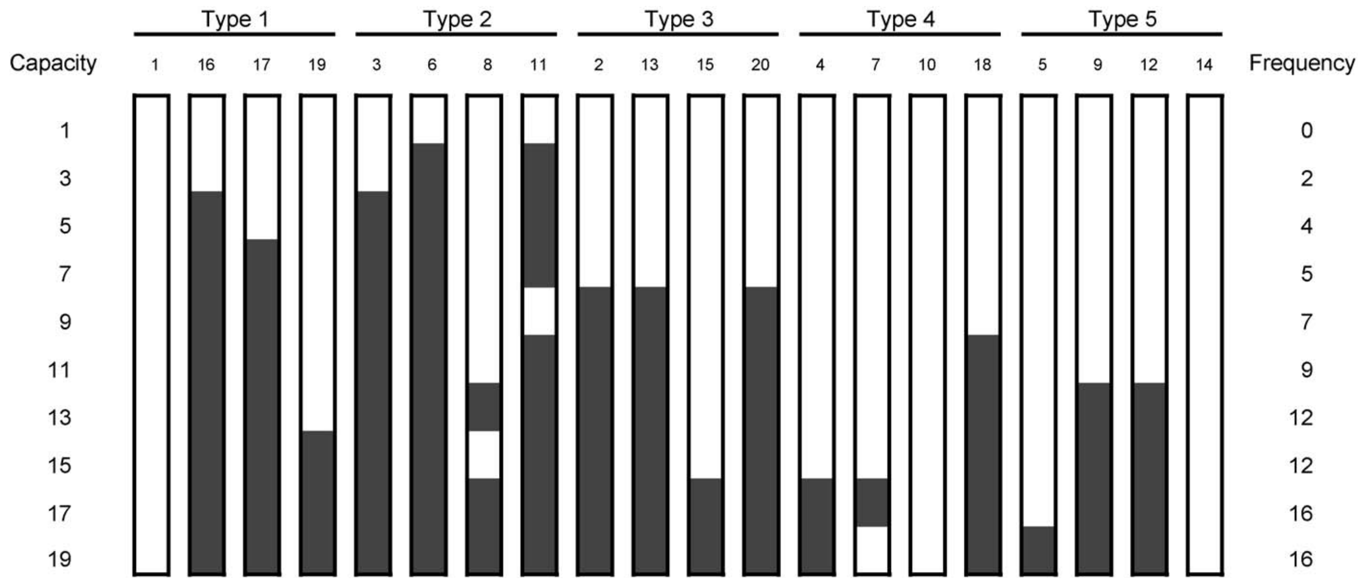
Key findings: (1) Little evidence of subjects in Group 1 using cutoff decision rules during the first 10 trials, (2) aggregate frequency of entry by market capacity shows violations of monotonicity.

Figure 5a. Displays the individual decisions for the first 10 trials for each subject in Group 1 of Rapoport, Seale, and Winter (1997). The shaded areas indicate entry decisions for a given market capacity. Type indicates the per-trial entry cost, whereas frequency refers to the aggregate number of entry decisions.



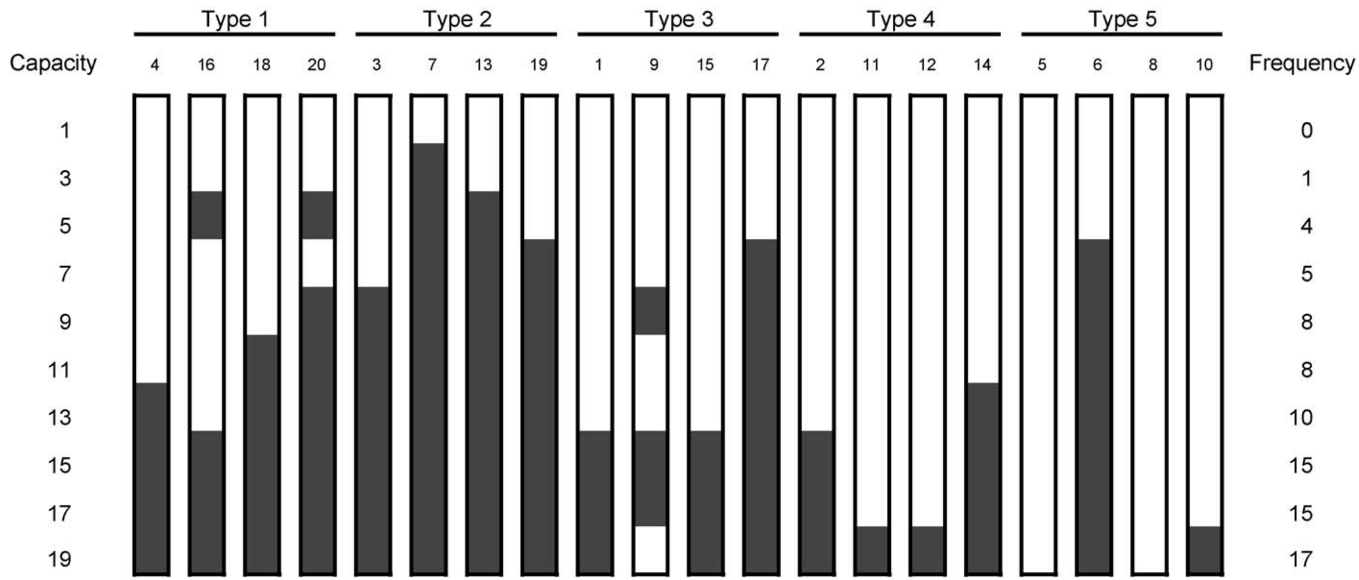
Key findings: (1) Little evidence of subjects in Group 2 using cutoff decision rules during the first 10 trials, (2) aggregate frequency of entry by market capacity shows violations of monotonicity.

Figure 5b. Displays the individual decisions for the first 10 trials for each subject in Group 2 of Rapoport, Seale, and Winter (1997). The shaded areas indicate entry decisions for a given market capacity. Type indicates the per-trial entry cost, whereas frequency refers to the aggregate number of entry decisions.



Key findings: (1) Most subjects in Group 1 appear to converge to a cutoff-type decision rule by the final block of trials, and (2) aggregate frequency of entry increases monotonically in market capacity.

Figure 6a. Displays the individual decisions for the last 10 trials for each subject in Group 1 of Rapoport, Seale, and Winter (1997). The shaded areas indicate entry decisions for a given market capacity. Type indicates the per-trial entry cost, whereas frequency refers to the aggregate number of entry decisions.



Key findings: (1) Most subjects in Group 2 appear to converge to a cutoff-type decision rule by the final block of trials, and (2) aggregate frequency of entry increases monotonically in market capacity.

Figure 6b. Displays the individual decisions for the last 10 trials for each subject in Group 2 of Rapoport, Seale, and Winter (1997). The shaded areas indicate entry decisions for a given market capacity. Type indicates the per-trial entry cost, whereas frequency refers to the aggregate number of entry decisions.

Table 5

Reports the number of entries by market capacity and player type for the two groups of Rapoport, Seale, and Winter (1997). Within each group, four players were assigned to each type, where type refers to the per-trial cost of entry. The number of entries within each cell may vary from 0 to 40

	Type					Across types
c	1	2	3	4	5	
Group 1						
1	0	0	1	0	2	3
3	0	14	2	0	3	19
5	11	22	6	1	2	42
7	13	19	13	3	6	54
9	14	26	17	9	11	77
11	18	30	27	13	10	98
13	18	30	30	14	16	108
15	29	27	32	20	18	126
17	29	35	36	22	18	140
19	30	39	37	29	23	158
Total	162	242	201	111	109	825
	Type					Across types
c	1	2	3	4	5	
Group 2						
1	0	2	6	1	0	9
3	5	13	2	1	1	22
5	5	20	6	7	0	38
7	12	29	10	8	7	66
9	16	32	15	7	12	82
11	22	38	13	8	12	93
13	34	35	19	11	14	113
15	37	37	22	22	16	134
17	39	39	33	21	15	147
19	38	39	34	35	18	164
Total	208	284	160	121	95	868

Key findings: The equilibrium solution is rejected as (1) entries are expected to decrease in type, (2) players of type 1 are predicted to always enter if the capacity is $\geqslant 9$, and (3) players of type 5 are predicted to never enter if the capacity is $\leqslant 15$.

3. Adaptive Learning

Taken together, the results of the market entry game experiments discussed above show remarkable coordination success in terms of the total number of entries for each value of c separately as well as the correlations between observed and predicted number of entries across values of c. These results stand in sharp contrast to the coordination failure reported by Van Huyck, Battalio, and Beil (1990, 1991, 1993) in a different class of coordination games. The Nash equilibrium is clearly rejected as a descriptive concept when the data are broken down by type or by player. There is considerable within-subject variability in the decision whether or not to enter a market with the same capacity, which is not due to randomization. In all the studies except Experiment 1 of Sundali, Rapoport, and Seale (1995) (where learning was not possible), there is evidence for a steady decline in the number of switches across blocks and convergence of individual behavior to cutoff decision rules with a cutoff point c^* that may change from block to block. This convergence is illustrated by comparing the individual profiles in Figures 5a and 5b to the ones in Figures 6a and 6b. Figures 5a and 5b display the individual profiles of all the forty subjects of Rapoport, Seale, and Winter (1997) in the first block of ten trials (Block 1), whereas Figures 6a and 6b portray the decision profiles of the same subjects in Block 10. Whereas there is only scant evidence for cutoff decision rules in Figures 5a and 5b, with experience most of the subjects (34 out of 40) converge to cutoff decision rules in Block 10 with marked individual differences in the value of c^* between and within types. The distribution of the cutoffs is a sufficient condition for coordination success. Reinforcement-based adaptive learning models of the kind proposed by Roth and Erev (1995) or by Daniel, Seale, and Rapoport (1998) account for the dynamics of play on both the individual and aggregate levels, thereby providing an explanation for the coordination success achieved in our experiments.

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