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Do institutions promote rationality? An experimental study of the three-door anomaly

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Abstract

The three-door problem is an example of a systematic violation of a key rationality postulate that has attracted much attention. In this seemingly simple individual decision task, most people initially fail to apply correctly Bayes' Law, and to make the payoff-maximizing choice. Previous experimental studies have shown that individual learning reduces the incidence of irrational choices somewhat, but is far from eliminating it. We experimentally study the roles of communication and competition as institutions to mitigate the choice anomaly. We show that the three-door anomaly can be entirely eliminated by these institutions.
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1. Introduction

Over the last decades, a vast literature has accumulated demonstrating that people violate basic rationality postulates of economics in many ways (see Camerer, 1995 for a survey). The empirical demonstration of these so-called choice anomalies has provided fruitful impulses to economics, stimulating research in fields like bounded rationality and behavioral economics (Rabin, 1998). The demonstration of these anomalies in individual choice is interesting in itself, and decision-making anomalies may have important economic

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consequences. However, skeptics of behavioral research argue that establishing that anomalous behavior is common at the individual level is insufficient to conclude that these anomalies translate into important effects in the economy and society (see Conlisk, 1996 for a discussion).

There are potentially many factors disallowing simple extrapolation from findings in the experimental laboratory to more complex environments in society and the economy. The two most important mechanisms affecting how individual irrationality translates into economic and social outcomes are *learning* and *institutions*. First, people may need some time to learn optimal decisions. This is particularly true if decision problems are unfamiliar to decision-makers or unusually complicated. Indeed, in many experiments behavior tends to converge to equilibrium choices over time (Camerer, 1995). Second, social and economic institutions may transform and possibly eliminate anomalies in individual choice (Frey and Eichenberger, 1994; Fehr and Tyran, 2002). For example, Becker (1962, p. 8) famously stated that households may be irrational and yet markets quite rational. “Some market environments, such as the double auction, are so powerful that they can generate aggregate rationality not only from individual rationality but also from individual irrationality” (Gode and Sunder, 1993, p. 119). Third, by a combination of the two mechanisms, social and economic institutions may also promote and facilitate learning, thereby promoting individual rationality.

This paper investigates the effect of learning and institutions on the incidence of rational decisions in the three-door problem, an apparently simple individual decision making task that has received an exceptional amount of attention from economists, statisticians, and the general public (see Morgan et al., 1991 along with the comments to the paper, including a letter from Marilyn vos Savant in the same issue). Expected payoffs of one option are twice as high as for the other option, and the problem has a clear rational choice prediction that is found by straightforward application of Bayes’ Law. Yet, the problem has “stumped scores of Ph.D. and confused the world’s most intelligent person” (Morgan et al., p. 287).[1] Moreover, people were found to choose systematically the inferior option in several experimental studies. Since Bayes’ Law is a key postulate of economic rationality, the anomaly seems to put into perspective the relevance of much work in the economics of uncertainty and information. In a thought-provoking paper, Friedman (1998) has investigated the first of the two mechanisms potentially invalidating this conclusion. He has shown that while the three-door anomaly can be considerably mitigated by providing experimental subjects with ample opportunities to learn, the anomaly is surprisingly persistent in an institution-free environment. Friedman (p. 942) notes that “despite the use of strong treatments, many subjects continued to make lots of irrational choices. The three-door anomaly declined substantially but did not actually disappear in 15 periods”.

Our study builds on Friedman and extends the study in three respects. First, we replicate one of Friedman’s treatments in a computerized environment that allows us to run the experiment for more periods, enabling us to investigate the effects of individual learning in more detail. Second, we investigate the effects of simple institutions on the incidence of non-rational behavior in the three-door task. In particular, we analyze how communication in groups and competition among decision makers affects the prevalence of the three-door

[1] We thank the co-editor for suggesting this quotation.

anomaly. Third, we investigate how the two mechanisms interact. That is, we analyze whether these institutions provide better learning environments.

Our results show that while learning from one's own experience has some mitigating effect, the effect fades, and the anomaly is strikingly persistent in an institution-free environment. For example, even after 40 repetitions of the task, the incidence of rational choices remains clearly below 50%. In contrast, the effect of competition and communication is immediate and strong. We show that each of these institutions strongly reduces the anomaly, and that if the two institutions are combined, the anomaly is completely eliminated. We observe an incidence of 100% rational choices in several periods when decisions are embedded in both of these institutions. This complete elimination can be partially be explained by improved learning in an institution-embedded environment. In particular, we show that learning and institutions interact.

The paper is organized as follows. Section 2 explains the three-door problem and briefly reviews the relevant literature. Section 3 explains the experimental design and presents results. Section 4 provides some concluding remarks.

2. Competition, communication, and the three-door anomaly

The three-door problem is inspired by a once-popular TV game-show hosted by Monty Hall. In the stylized version of the game studied in the experiments, a subject first chooses between three options, called doors. Only one of these doors hides a prize while the other two doors return no payoff. However, the chosen door is not immediately opened. Rather, one of the remaining two doors that does *not* contain the prize is opened by the experimenter.[2] Next, the subject is asked whether he or she would like to *remain* with the initial choice or *switch* to the other unopened door. The rational choice is to switch to the door not initially chosen, since switching doubles the odds of winning the prize from 1/3 to 2/3. This follows from a straightforward application of Bayes' Law. Call the three doors A, B, and C. Suppose the subject initially chooses door A. Assume that the experimenter opened door B. The exact probability of winning the prize by switching to door C therefore is

$$\begin{aligned}
&\Pr(\text{prize behind C}|\text{experimenter opens B})\\
&\quad = \frac{\Pr(\text{experimenter opens B}|\text{prize behind C}) \times \Pr(\text{prize behind C})}{\Pr(\text{experimenter opens B})}\\
&\quad = \frac{(1)(1/3)}{(1)(1/3) + (1/2)(1/3)} = \tfrac{2}{3}
\end{aligned}$$

The intuition for this result is as follows. If the subject initially chooses randomly among the three doors, he or she finds the prize with a probability of 1/3 and does not find the prize with 2/3. Since the experimenter must open a non-chosen door that does not contain the prize, the strategy *switch* is guaranteed to yield the prize whenever the door containing the prize was not chosen in the initial choice (i.e., in 2/3 of the cases). As a consequence, the strategy remain yields the prize only when the door containing the prize was randomly chosen in the first trial (i.e., in 1/3 of the cases).

[2] The experimenter chooses randomly if there is a choice between two doors that do not contain the prize.

The three-door problem has been studied in a number of controlled laboratory experiments by psychologists (e.g., Granberg and Brown, 1995; Gilovich et al., 1995) and economists (e.g., Page, 1998; Palacios-Huerta, 2003). A result common to all experiments is that a large majority of experimental subjects do not switch but rather choose to remain with their original choice. The number of decisions to switch as a percentage of all decisions, the *switch rate*, typically is below 20% in these studies (Granberg, 1999). Friedman demonstrated that the anomaly is also surprisingly persistent when experimental subjects are given the opportunity to repeat the task (including full statistical information about past behavior), and when they are provided with various learning aids. While switch rates increased upon repetition of the task, they remained below 60%.

The systematic and persistent violation of rationality has awarded the three-door problem the status of a leading choice anomaly for several reasons. First, the three-door choice task is simple in comparison to choices required in many economic settings (there are only two options to choose from in the second stage). Second, the anomaly is surprisingly persistent, and despite the apparent simplicity of the problem the optimal choice seems to be exceedingly difficult to learn. Thus, Friedman (p. 936) states: “Indeed, I am not aware of any anomaly that has produced stronger departures from rationality in a controlled laboratory environment.” Third, the three-door problem is a straightforward application of Bayes’ Law, and since Bayes’ Law is a central building block of modern economic theory, the anomaly seems to cast serious doubt on the predictive power of the economics of uncertainty and information.

In order to test the impact of institutions on rationality, we study two simple settings that are hypothesized to reduce the prevalence of the anomaly. Our experiment involves a 2×2 design. In all four conditions, subjects repeat the task several times and are provided with immediate feedback about the outcomes of their decisions, enabling them to learn from their own experience. The treatments differ with respect to communication and competition.

Communication is a natural feature in all social settings, including economic decisions (e.g., Blinder and Morgan, 2000). While it seems plausible that the additional brain power available to groups tends to foster rationality, the claim that groups make more rational decisions as general rule seems to be wrong. Whether individuals or groups perform better depends, in general, on both the nature of the task and the process of decision making within the group (see Davis, 1992 for an overview). In our study we introduce communication by having small groups of subjects instead of isolated subjects take the three-door task.

Competition has long been trusted to correct for irrational behavior (see, e.g., Arrow, 1987). Empirical evidence, however, is mixed in that some anomalies disappear in market settings while others are surprisingly persistent (see Knez et al., 1985; Camerer, 1987; Cox and Grether, 1996; List, 2003; Hung and Plott, 2001; Budescu and Maciejovsky, 2003). Competition was implemented in the present study by rewarding experimental subjects’ performance relative to the performance of other subjects (or groups of subjects). The rank-order competition we implement is public in that all information concerning behavior, outcomes, and the relative standings of all contestants are made public repeatedly in the course of the experiment. This allows contestants to compare their relative performance and to learn from the behavior of others.

Table 1
Overview of treatments

Competition	Communication	
	No	Yes
No	*Base line* BASE (12 individuals)	*Communication* COMM (33 in groups of 3)
Yes	*Competition* COMP (12 individuals)	*Competition and communication* CC (36 in groups of 3)

Notes: the number of experimental subjects is given in parentheses. All subjects and groups of subjects repeated the task 40 times.

3. Experiment

Section 3.1. explains the experimental design and the procedures. Section 3.2. presents the main results, and Section 3.3. provides an econometric analysis of learning and institutions. In Section 3.4., we provide a discussion of why the three-door anomaly is so persistent in an institution-free environment.

3.1. Design and procedures

Our experiment involves a total of four treatments. A 2×2 design (see Table 1) was chosen to isolate the effects of competition and communication, to evaluate their comparative relevance, and to detect potential interaction effects. All treatments have in common that the three-door problem is repeated for 40 periods and that track record information is provided automatically by the computer for each period. Track record information means that subjects obtain information about their own past decisions and their own cumulative earnings, as well as about hypothetical cumulative earnings for the strategies "always remain" and "always switch".

The treatment (BASE) is a replication of Friedman's "track record" treatment. It serves as a control treatment against which the effects of communication and competition can be evaluated. In BASE, subjects face the three-door problem in an *institution-free environment*. Subjects worked individually and proceeded at their own pace.[3] Subjects earned 10 points each time the prize was found, and 0 points otherwise. Points were accumulated throughout the experiment and converted into money at a commonly known exchange rate of 0.75 Swiss Francs (0.50 US$, approximately) for 10 points at the end of the session when subjects were paid their earnings in cash.

The competition treatment (COMP) differs from BASE in that the exchange rate depends on the relative standing or rank of a subject's cumulative earnings compared to others as shown in Table 2. Hence, rank-order competition was introduced by ranking the 12 subjects

[3] In each period, subjects are shown a sequence of three screens. The first screen shows three closed doors, and subjects choose one of the doors by clicking on it. On the second screen, one (non-chosen, empty) door is opened by the computer, and the subject chooses between *remain* and *switch* by clicking on a button. On the third screen, the computer opens the remaining doors, indicating where the prize was hidden and whether the subject won.

Table 2
Payment scheme for rank-order competition

Rank	Rate
1	1
2	0.95
3	0.9
4	0.85
5	0.8
6	0.75
7	0.7
8	0.65
9	0.6
10	0.55
11	0.5
12	0.45

Notes: Rank refers to a subject's (or group's) relative position in terms of cumulative earnings. *Rate* is the exchange rate in Swiss Francs at which 10 points are converted into cash. Table 2 was used in COMP and CC.

involved in this treatment according to their cumulative points earned at the end of the session, and subjects were paid according to the exchange rate associated with their rank in period 40. This procedure, including Table 2, was explained to subjects at the beginning of the experiment (instructions are availble from the authors upon request). Furthermore, in order to inform subjects about their relative standings during the experiment, at the end of rounds 10, 20, 30, and 40, the cumulative points and the decisions of all 12 subjects were publicly displayed on screens. That is, subjects were informed about how often other subjects chose to remain or switch on all previous trials, allowing subjects to assess their own relative success up to that point in time and to compare their own behavior with that of others. It should be stressed, however, that subjects were unable to identify the identity of other subjects by this information.

It should be noted that the rank-order competition we implement differs from standard tournaments in that competition does not affect the optimal choice. Hence, competition would be irrelevant if all contestants were rational and egoistic. For such an agent, switch is the dominant choice irrespective of what others do. However, in the presence of rank-order competition the average sanction for being irrational is higher if the number of rational competitors is higher. In this sense, rank-order competition provides additional incentives to make or learn the rational choice.

The communication treatment (COMM) involved 11 separate groups of three subjects each. Each group faced the same task as in the base line treatment. Groups, however, had to discuss their decisions and act as a single decision maker. In the event that they did not agree on a decision, group members had to vote decision by the group based on a simple majority rule. However, most decisions were taken unanimously. Communication was allowed only within groups, but never between groups.[4] The payment scheme was

[4] Each group of three subjects was seated in front of one computer, but computers were separated such that members of one group could not see decisions of other groups. Groups were asked to discuss at low voice in order not to disturb the deliberation of other groups. Discipline among participants was very good.

identical to that in BASE (i.e., there was a fixed exchange rate of 0.75 Swiss Francs for each prize found), and each group member received the monetary outcome earned by the group.

Finally, treatment (CC) combines both institutions. While there was communication within groups of three subjects (as in COMM), there was also rank-order competition between the 12 groups as in the COMP treatment (see Table 2). Treatment CC serves to test for possible interaction effects of the two institutions.

It is worthwhile to repeat differences in available information among treatments. While decision makers are provided with summary statistics about their own actual decisions and the strategies "always switch" and "always remain" in all treatments, decision makers in COMP and CC obtain additional information. At the end of periods 10, 20, 30, and 40, they are informed about actual choices and relative standings of all contestants. Hence, this additional information provides opportunities for imitation learning. In the treatments involving communication (COMM and CC), learning from others is also possible. To provide an extreme example, assume that a third of all subjects understands the Bayesian logic and that these subjects are evenly spread among all groups. If these subjects succeed in convincing at least one other group member to switch, one would observe 100% switching. Hence, social learning through persuasion provides a potential leverage for rationality with communication.

A total of 93 freshmen from the University of St. Gallen volunteered for participation. They were allocated randomly to the treatments. All four treatments were run simultaneously in four different rooms so that no information about the content of the experiment could leak to subjects before the experiment started.

3.2. Main results

Our presentation of results focuses on the incidence of rational decisions (i.e., the relative frequency of decisions to switch to the unopened door not initially chosen). Fig. 1 shows these switch rates averaged over blocks of five periods. The figure shows that switch rates differ substantially between treatments from the beginning of the experiment. Average switch rates in periods 1–5 are 13% (BASE), 22% (COMP), 29% (COMM), and 45% (CC), respectively. Fisher's exact tests reveal that BASE is different from each of the other treatments at the 10% level.[5] Therefore, we observe immediate treatment effects: communication by itself and the incentive from competition by itself have a marked impact. For example, switch rates are about twice as high when subjects make decisions in groups and hence communicate within their group (COMM) than when they take decisions in isolation (BASE). When communication and competition are combined (CC), we observe another significant treatment effect (exact Fisher tests for periods 1 to 5 provide the following results: CC versus COMP: $P = 0.004$, CC versus COMM: $P = 0.033$). Switch rates in CC are about twice as high as in the absence of communication, and about three times as high as in the absence of communication and competition. Note that the significant immediate treatment effects in the treatments involving competition (i.e., COMP and CC) do not arise

[5] Exact Fisher tests for periods 1–5 provide the following results: BASE versus COMP: $P = 0.094$, BASE versus COMM: $P = 0.022$, BASE versus CC: $P = 0.000$.

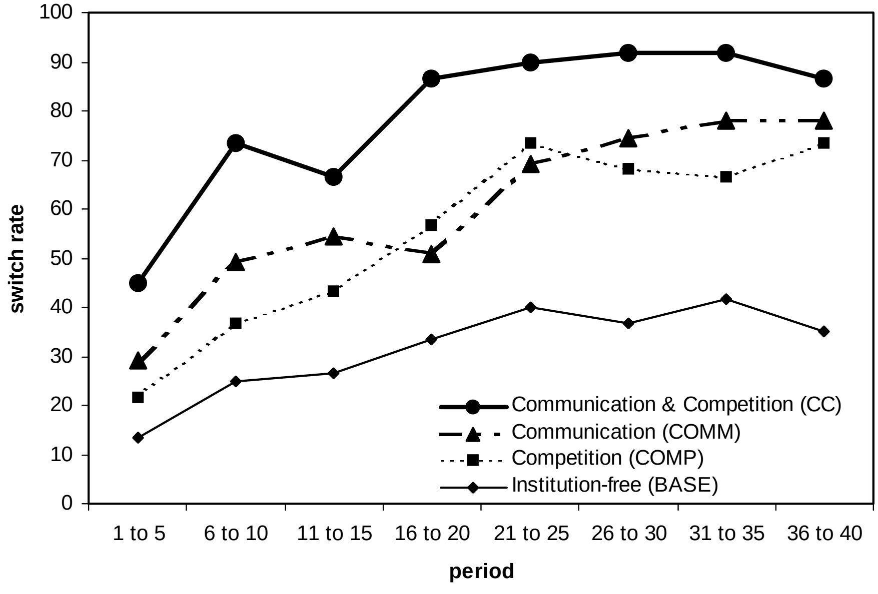

Fig. 1. Switch rates in blocks of five periods.

from imitation learning, since information about one's own rank and about the decisions of the competitors is revealed for the first time at the end of period 10. Interestingly, this information did not seem to improve switch rates. In both COMP and CC the switch rates are not significantly different in periods 10 and 11 according to a Fisher Exact test at the 10% level. Also, the effect of institutions on the rationality of behavior appears to be very *persistent*. From period 16 on, for instance, the difference in average switch rates between CC and BASE is never less than 50% points (see Fig. 1).

Subjects appear to learn from experience in all treatments. As can be seen from Fig. 1, by the end of the experiment (periods 36–40), average switch rates have increased to 35% (BASE), 75% (COMP), 78% (COMM), 87% (CC). Note that average switch rates in the treatments involving institutions are now more than twice as high as in the institution-free treatment BASE. Therefore, it is not only the case that competition and communication improve the rationality of decisions from the very beginning of the experiment, but these institutions also provide better learning environments. To illustrate, the overall increase in the switching rate in the institution-free treatment BASE is only about 20% points, whereas the increase is almost 50% points in the treatments involving communication and competition. However, most of the learning appears to take place in the first 25 periods because thereafter we observe switch rates even to fall in some periods (see Fig. 1). Thus, we do not find support for Friedman's (p. 940) suggestion that "subjects would choose switch more than 90% of the time after about $T = 60$" in the institution-free treatment (BASE).

These main results suggest that strong information and repetition alone does not seem to be a sufficient condition for fully rational behavior in this task. Quite strikingly, the average switch rate in periods 31–40 in BASE is a mere 38.3%, clearly below what would result from purely random choice between the two options. At the same time, the data strongly suggest that the three-door anomaly can be entirely eliminated in environments that provide rich opportunities and strong incentives for learning such as institutions of communication and competition. In particular, we find switch rates of 100% in two treatments involving institutions in several periods (in COMM: period 33; in CC: periods 27, 33, 40).

3.3. Econometric analysis

Following Friedman, we estimate a simple learning model. In addition, we isolate the effects of communication and competition on the probability to switch and analyze interaction effects between learning and institutions. The variables *Switchbonus*, *Switchwon* and *Switchlost* are suggested by learning theories. Reinforcement learning (see Erev and Roth, 1998) suggests the variable *Switchbonus*, defined as the earnings from always switching minus earnings from always remaining, cumulated from the first period to the most recent period. Directional learning (see Selten and Buchta, 1998) suggests *Switchwon*, a dummy variable equal to 1 if the decision maker switched and won the prize in the most recent period. Analogously, *Switchlost* is equal to 1 if and only if the decision maker switched in the preceding period but did not win the prize. We also estimate the effects of communication and competition. The variable *Competition* is equal to 1 if payoffs depended on the ranking of points relative to other decision-makers, as explained in Table 2. Hence, *Competition* is a dummy variable equal to 1 in treatments COMP and CC. Analogously, the variable *Communication* is equal to 1 in treatments COMM and CC. Finally, the variable *Competition* × *Communication* captures the interaction effect between competition and communication and is equal to 1 in treatment CC.

Table 3 shows the results from a maximum-likelihood probit estimation of the marginal effects d*F*/d*x* in column (2). These estimates show the change in probability for an infinitesimal change in the independent continuous variable and the discrete change in the probability for dummy variables. The table shows that both learning theories have some predictive success. As can be seen from the coefficient of *Switchbonus*, the effect of a subject's cumulative history seems to be relatively minor in size, although cumulative experience of additional success from switching (with each success yielding an income of 10 points) increases the probability to switch by 1.7%. The effects of the most recent experience, captured by *Switchwon* and *Switchlost*, are very pronounced. In particular, the probability of switching is 32.2% higher if switch was chosen in the preceding period and won. The probability to switch is 21.5% lower if switch was chosen in the preceding period but lost. These findings are sharper, but generally in line with the results obtained by Friedman (p. 944). The positive estimate for *Time* indicates that there is some overall trend increasingly to choose switch that is not captured by the other learning variables, and the negative coefficient for the variable $Time^2$ indicates that this trend is non-linear and falling over time.

The second group of variables in Table 3 shows that the effects of competition and communication are similar in magnitude and that the two effects are independent. In particular, the coefficient for the variable *Competition* shows that competition increases the probability of switching by 14.4%, and communication does so by 15.5%. Interestingly, there are no

Table 3
Marginal effects from probit estimation

Dependent Var. switch	dF/dx (2)	S.E. (3)	z (4)	P > |z| (5)
Learning				
Switchwon	0.3323	0.0486	6.14	0.000
Switchlost	−0.2149	0.0518	−4.09	0.000
Switchbonus	0.0017	0.0005	2.99	0.003
Time	0.0135	0.0054	2.49	0.013
Time^2	−0.0003	0.0001	−2.66	0.008
Institutions				
Competition	0.1435	0.0675	2.10	0.035
Communication	0.1549	0.0670	2.29	0.022
Competition × *Communication*	0.0468	0.0523	0.89	0.375
Interaction of learning and competition				
Competition × *Switchwon*	−0.1434	0.0649	−2.21	0.027
Competition × *Switchlost*	0.1407	0.0571	2.31	0.021
Competition × *Switchbonus*	−0.0006	0.0007	−0.82	0.415
Competition × *Time*	0.0057	0.0032	1.77	0.076
Interaction of learning and communication				
Communication × *Switchwon*	0.0032	0.0639	0.05	0.961
Communication × *Switchlost*	−0.0964	0.0651	−1.49	0.136
Communication × *Switchbonus*	−0.0019	0.0007	−2.59	0.010
Communication × *Time*	0.0089	0.0032	2.76	0.006

Number of observations = 1880, Log likelihood = −956.88, Pseudo $R^2 = 0.2571$.

significant interaction effects between communication and competition. The insignificant estimate for *Competition* × *Communication* indicates that the effectiveness of one institution does not depend on the level of the other. Therefore, the effects of the two institutions are basically additive in our analysis.

The third and fourth group of variables in Table 3 serve to analyze whether institutions provide better learning environments. Here, we interact the institution variables with the learning variables. As can be seen from the table, the interaction of *Competition* and *Switchwon* and *Switchlost* is rather strong. This indicates that in the presence of competition decision makers react less to the most recent experience. The estimate for the interaction between *Competition* and *Switchbonus* is insignificant, suggesting that competition by itself does not improve learning from accumulated experience. However, in the presence of competition, there is an additional (weakly significant) positive effect on the tendency to choose the rational action, as can be seen from the coefficient *Competition* × *Time*.

The last group in Table 3 shows that communication per se does not lead to a significantly different reaction to the most recent experience (see insignificant estimates for interaction with *Switchwon* and *Switchlost*). However, somewhat surprisingly, groups are less able to infer the rational solution from accumulated experience than individual subjects as is indicated by the negative coefficient for *Communication* × *Switchbonus*. Whether this finding is indicative of free-riding within groups or of “groupthink” remains unclear. It is important to note, however, that communication induces additional rationality over time. This is indicated by the positive estimate in the last line.

We conclude the following from this analysis. First, there is significant learning that can at least partially be explained by leading learning theories. Second, institutions promote rationality in that they lead to higher levels of switch rates. Third, learning interacts with institutions in the sense that institutions provide better learning environments. The learning theories we have tested, however, fail to account for the bulk of improved learning. The institutions under investigation affect learning quantitatively and qualitatively. Graphically speaking, institutions both shift the "switch trajectory" of Fig. 1 upwards and at the same time make it steeper.

3.4. Why is the three-door anomaly so persistent?

Practice improves performance, and our experiment is no exception to this rule. We observe a clear increase in rationality over time in all treatments, and the variables suggested by learning theories have been found to be highly significant. However, consistent with the so-called power law of practice (Erev and Roth), we observe that learning is more pronounced in early periods and fades over time. In all treatments, most of the improvement in rationality takes place in the first 20 periods. While there is significant learning in the early periods, switch rates in our institution-free treatment (BASE) remain strikingly low throughout the experiment. For example, the average switch rate in the last five periods (periods 35–40) is still clearly worse than the 50% that would result from completely random choice among the two alternatives.

Why is learning so slow in the institution-free treatment? It seems to be the case that the intuition of equal chances of winning for the two options is so strong that feedback information indicating the superiority of switching is simply ignored, and is, instead, attributed to chance (see Slembeck, 2002 for a more detailed pychological account).

We now illustrate how difficult it is to learn the rational choice for someone believing the two options to be equal but (for the sake of the illustration) being otherwise trained in statistics. Suppose a subject holds the Null hypothesis Prob(switch) $=$ Prob(remain) but is willing to reject the hypothesis in favor the alternative hypothesis that Prob(switch) $>$ Prob(remain) if sufficient evidence accumulates against the Null hypothesis. When can this Null hypothesis be rejected at the confidence level $\alpha = 0.05$? Suppose the decision maker observes that switch won seven times after 10 periods (i.e., suppose 7 "successes" out of 10 "trials"). According to a Binomial test, the one-tailed probability is $\text{Prob}[Y \geq 7, N = 10, P = 0.5] = 0.172$. Since $0.172 > \alpha$, the Null hypothesis cannot be rejected. The same is true of 14 successes after 20 periods since $\text{Prob}[Y \geq 14, N = 20, P = 0.5] = 0.058 > \alpha$. The hypothesis can be rejected by a very narrow margin with 20 successes after 30 periods ($\text{Prob}[Y \geq 30, N = 30, P = 0.5] = 0.049 < \alpha$) and can be more clearly rejected with 27 successes after 40 periods ($\text{Prob}[Y \geq 27, N = 40, P = 0.5] = 0.0195 < \alpha$). Note that these examples involve cases that are close to the expected values of successes (i.e., $(2/3)N \cong$ #successes). However, if the evidence by bad luck is slightly less favorable, it may not be possible to reject the Null hypothesis even after 40 periods. For example, suppose only 25 successes are observed after 40 periods. In this case, $\text{Prob}[Y \geq 25, N = 40, P = 0.5] = 0.077 > \alpha$. Note that observing 25 or fewer successes of switch in 40 trials is quite probable (34.2%). Hence, this exercise illustrates that the (wrong) belief that switch and remain are equally likely to be successful is more difficult to reject with less experience and is quite likely not to be rejected even by the end of the experiment.

4. Conclusions

We show that a combination of competition and communication yields behavior that converges quite closely to the rational solution upon repetition of the three-door task. Given the striking persistence of the anomaly with regard to repetition in an institution-free environment (as in BASE), our study presents evidence for strong effects of social institutions, such as communication in groups, as well as economic institutions, such as rank-order competition, for convergence toward rationality. When both institutions are combined, information processing and learning appear to be much improved, and the anomaly can be entirely eliminated.

Three remarks on the broader implications of our results with respect to the relevance of anomalies seem appropriate. First, the fact that we succeed in eliminating the three-door anomaly does not imply that *every* choice anomaly will be entirely eliminated by communication and competition. The three-door anomaly is a particularly clear-cut case of a cognitive limitation: a failure to choose the income-maximizing option when no motive other than money-aximization can plausibly be invoked. However, if “anomalies” involve non-selfish motives (e.g., fairness, reciprocity), even fiercest competition may not induce behavior consistent with standard economic predictions (see Fehr and Falk, 1999).

Second, our finding that people learn to overcome the three-door anomaly when they communicate and compete—as they do in everyday life—does not imply that this (or any other) anomaly is irrelevant in everyday economic and social interaction. The reason is that learning may be considered as slow and requires several repetitions in our experiment. One may reasonably question whether “stationary replication” is a natural feature of everyday life (Loewenstein, 1999). Therefore, it remains an open empirical question and a matter of application whether the relatively low incidence of rational decisions we observe in the early periods or the very high incidence of rationality observed in late periods is more representative for behavior outside the laboratory (and should be taken as an indication of how relevant violations of Bayesian updating are).

Third, while we show that simple and natural institutions can eliminate the three-door anomaly, our study cannot be more than a small step in the long-term endeavor to understand when and why institutions promote rationality. As is well known from much research in experimental economics, subtle changes in the institutional design may strongly alter behavioral effects. Hence, how much our results hinge upon the design of our experiment with regard to group size, the competition mechanism, and the type of information feedback remains an open question.

In all, we believe that the debate on anomalies can be made more fruitful if future research not only investigates the existence and non-persistence of anomalies, but also explores how robust these anomalies are with respect to socially and economically relevant institutions.

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