

Three doors anomaly, “should I stay, or should I go”: *an artefactual field experiment*

Andrea Morone^a, Rocco Caferra^a, Alessia Casamassima^a, Alessandro Cascavilla^a, Paola Tiranzoni^a

^a Bari University “Aldo Moro”, Department of Economics, Management and Business Law, Italy.

Abstract: This work aims to identify and quantify the biases behind the anomalous behavior of people when they deal with the Three Doors dilemma, which is a really simple but counterintuitive game. Carrying out an artefactual field experiment and proposing eight different treatments to isolate the anomalies, we provide new interesting experimental evidence on the reasons why subjects fail to take the optimal decision. According to the experimental results, we can quantify the size and the impact of three main biases that explain the anomalous behavior of participants: *Bayesian updating*, *illusion of control*, and *status quo bias*.

Keywords: Three doors anomaly; Cognitive Bias; Bayes equilibrium; Probability; Decision-Making; Field experiments; Artefactual experiments; Behavior; Bounded rationality.

JEL:

1. Introduction and Literature Review

“Suppose you're on a game show, and you're given the choice of three doors: behind one door is a car; behind the others, goats. You pick a door, say No. 1, and the host, who knows what's behind the doors, opens another door, say No. 3, which has a goat. He then says to you, ‘Do you want to pick door No. 2?’ Is it to your advantage to switch your choice?”¹ The optimal choice, switching to pick door No. 2, should be not so hard to find (for the homo oeconomicus). People, however, seem to do not behave accordingly. This is the case of the famous TV show “Let's Make a Deal”, in which a presenter (Monty) and a participant play a game called the “Monty Hall's three doors”. It is a really simple but counterintuitive game, in which there are three ordered doors. Behind these three doors, there are respectively: one prize (a luxury car) and two non-prizes (goats). The participant is supposed to find the prize (a luxury car) that is hidden behind one of the three doors. It is a two-stage sequential game as follows:

¹ vos Savant, Marilyn (17 February 1991a). [“Ask Marilyn”](#). Parade Magazine: 12.

- (1) The participant chooses one of the three doors, and the door is left closed;
- (2) The host opens one of the two left doors with a goat behind;
- (3) The host asks the participant to decide whether to keep his initial door or to change it with the other closed door.

At this point, the intuitive thought of the participant could be that it is indifferent whether to keep staying or switch. However, following the Bayesian probability theorem, we know that this intuition is wrong, and the optimal choice should be to switch. If one keeps his initial door, the probability of winning remains $1/3$, as it was in point (1), while in case of switching the probability rises to $2/3$. Despite it seems quite straightforward, most people seem to do not consider this conditional probability but makes often the wrong choice.

The Monty Hall problem has been deeply studied across several fields, from mathematics, psychology, physics to economics. Even though it seems a simple probabilistic game, it is hard to explain the systematic and self-determined irrational behavior of the major of participants. The debate is still open and it seems to be an endless problem. The choice of not switching, reducing dramatically the probability of winning, could be caused by different reasons. Friedman (1998) focuses his reasoning on four main factors: (i) gambler's fallacy, (ii) endowment effect, (iii) probability matching, (iv) Bayesian updating.

Through gambler's fallacy (also called "illusion of control" by Camerer, 1995) participants are self-convinced to be able to control more than they really can, showing some intuitive skills in choosing the most likely door with the prize behind. Moreover, a kind of endowment effect bias can be found in explaining the anomalous choice. Since a participant already chooses one of the three doors, when he is supposed to decide whether to switch or to stick, he would not switch because he considers his initial choice as the endowment, without considering it as a sunk decision². It seems that people ascribe more value to things merely because they already own them. Another important behavior that comes out from the experimental design of Friedman (1998) is the probability matching behavior, which is an anomalous and irrational behavior through which people choose according to the likelihood of each alternative rather than the real most likely one. Despite all these three already mentioned reasons are very relevant in explaining the reluctance to switch the choice, even though it should be the most rational one, there is another fundamental problem in the Monty Hall dilemma, which is considered to be the most important by the literature in various fields: participants fail in Bayesian updating. When the initial choice is made and the information of the empty door is given to the participant, the Bayesian probability of winning is $1/3$ for the initially picked door and of $2/3$ for the other alternative. People seem to do not notice this updating of probability, or they are not able to understand this simple but counterintuitive problem.

² See the "Sunk cost fallacy": Arkes & Blumer, *The psychology of sunk cost* (1985); the "Prospect theory": D. Kahneman & A. Tversky, (1979).

On this wise, Franco-Watkins et al. (2003) state that human reasoning does not always adhere to the formal rules of logic. For instance, the expected utility or Bayesian theorem fails to be effective in reality. Baratgin (2015) noticed that people often use subjective Bayesian reasoning for solving complex problems in which different solutions can be envisaged depending on the interpretations made by participants.³ Hence, one may think that the Monty Hall anomaly is all about a problem of the misunderstanding of Bayesian probabilities or subjective conditional probabilities. In reality, it may be not the case, or better, it is not the unique cause that leads to the anomalous behavior of participants. For this purpose, experimental studies have tried to modify the original Monty hall game proposing several treatments, trying to capture different effects according to specific control variables.

Many experiments attempted to address this unsolved dilemma. By employing an iterated version of the game, Palacios-Huerta (2003) showed that different monetary incentive amounts, individuals' initial abilities, and social interactions affect the learning individual and group behavior in the Monty Hall problem. They found that, in earlier stages, the more able students make the optimal choice (on average with a switching rate of 18 percentage points in the first 5 rounds) respect to the less able students. Moreover, individual interaction along rounds incremented the probability to take the right choice. On the other hand, Franco-Watkins et al., (2003) ran three different experiments to study – in the first two cases – if choice behavior and probability judgments can be influenced by learning from another simulated game similar to the Monty Hall problem and – in the last one – if changes in the number of doors and the size of prizes can influence participants behavior. In the first two treatments, they found that participants learned to switch to the optimal choice, maybe they are not able to soundly motivate their strategy. Thus, they get just implicit knowledge of the game, indeed they did not understand that switching is the theoretical optimal solution to increase the likelihood to win. From the last treatment, the authors found that subjects portioned their probability judgment based on the number of prizes over the number of unopened doors. Continuing, Morone and Fiore (2008) tested whether the Bayesian updating bias disappeared with a treatment “for dummies” in which participants were not supposed to compute any probability updating. However, although the share of switching behavior has increased, the irrational behavior of not switching did not completely disappear. Thus, the Monty Hall anomaly is not only linked to the limited capacity of Bayesian updating but other reasons, mainly psychological, play an important role in the choice of participants. According to Morone and Fiore (2008), the “status quo bias” could have an effective impact on the anomalous behavior of players. People seem to attribute a higher value on the initial choice, probably because they feel their choice as an initial endowment, and their loss aversion makes them surer in case they do not switch the initial choice. Participants give more value to their choice, only because they think they own them, and this justifies the fact that at least 15% of the experiment participants never decided to switch. Finally, Petrocelli and Harris (2011) studied the linkage between learning, counterfactual thinking, and memory for decision/outcome frequencies. Their main result is that subjects are reluctant to switch doors.

³ See the “Sleeping Beauty problem”, Baratgin and Walliser, 2010; Mandel, 2014.

The counterfactual thinking⁴ makes learning the Monty Hall problem more difficult, because it puts subjects in the position to do not understand the optimal choice, especially when the premium increases. At the same time, memory for decision/outcome frequencies makes learning the actual associations between switch decisions and winning and stick decisions and losing, difficult to understand.

To the best of our knowledge, the literature lacks paper which (i) jointly removes both the Bayesian updating and the illusion of control biases and (ii) accounts for a different game solution.

We provide an artefactual field experiment, carried out in a mall in Bari (Italy), to isolate the different reasons behind the irrational choice of participants.

2. Experimental Design

We conducted an artefactual field experiment in a mall in Bari (Italy) in October 2019, interviewing a total amount of N=681 subjects⁵.

In the questionnaire (see annex), we have six socio-demographic questions. The last question concerns *Monty Hall's three doors*. In all eight treatments, we have three boxes and only one of these contains a prize, i.e. a 10 € banknote the other two boxes are empty.

In **T1**, the Control treatment, subjects were asked to choose a box among three and an empty un-chosen box was subsequently opened. Then, we asked subjects if they want to switch their first choice with the remaining un-chosen box. In this treatment are presented the three biases discussed in the previous paragraph:

- the illusion of control: subjects believe that they may understand which choice is better and they consider the first choice as the most likely;
- the status quo bias/endowment effect: subjects seem to give higher value on their first choice, maybe because they are loss averse and because they think they own it;
- the Bayesian updating: the opening of the empty box creates new information i.e. the probability that the first chosen had a reward was 1/3 and it was steady and the probability that the open box concealed the reward became 0. Finally, the probability that the last door had a reward was 1/3 and it became 2/3.

T2 is identical to **T1** but we removed the Bayesian updating. Also, in this treatment subjects were asked to choose a box among three, but in this treatment, no doors are opened after the subject choice and, then we asked subjects if they want to switch their chosen box with the other two boxes. In this treatment are presented

⁴, in that case, upward counterfactual thinking (i.e., simulating alternatives that are more desirable than reality; Markman, Gavanski, Sherman, & McMullen, 1993) has been applied.

⁵ N= 80 in T1, N=72 in T2, N=88 in T3, N=79 in T4, N=96 in T5, N=88 in T6, N=87 in T7 and N=91 in T8.

only two of biases discussed in the previous paragraph:

- the illusion of control;
- the status quo bias/endowment effect.

In **T3** subjects were assigned one box among three and then one empty box is opened, and we asked subjects if they want to switch their assigned box with the remaining not opened one. In this treatment are presented only two biases:

- the Bayesian updating;
- the status quo bias/endowment effect.

T4 is identical to **T3** but we removed the Bayesian updating. Subjects were assigned one box among three and then we asked them if they want to switch their assigned box with the two remaining boxes. In this treatment, there is only one bias:

- the status quo bias/endowment effect.

In **T5** subjects were asked to choose two boxes among three. Then, an empty box of the two chosen boxes is opened and we asked subjects if they want to switch both their chosen boxes with the remaining box. In this treatment, there are all biases:

- the illusion of control;
- the Bayesian updating;
- the status quo bias/endowment effect.

In **T6** subjects were asked to choose two among three boxes. We asked subjects if they want to switch both their chosen boxes with the remaining box. In this treatment, there are only two biases:

- the illusion of control;
- the status quo bias/endowment effect.

In **T7** subjects were assigned two boxes. Then, an empty box of the two assigned once is opened and we asked subjects if they want to switch both their assigned boxes with the remaining box. In this treatment there are only two biases:

- the Bayesian updating
- the status quo bias/endowment effect.

Finally, in **T8** subjects were assigned two among three boxes. Then, subjects were asked if they want to switch both their boxes with the remaining box. In this treatment is presented only one bias:

- the status quo bias/endowment effect.

In table 1 we summarize the biases that are present in each treatment.

Treatment	Optimal choice	Bias		
		Illusion of control	Endowment effect	Bayesian updating
T1	Change	✓	✓	✓
T2	Change	✓	✓	✗
T3	Change	✗	✓	✓
T4	Change	✗	✓	✗
T5	Stay	✓	✓	✓
T6	Stay	✓	✓	✗
T7	Stay	✗	✓	✓
T8	Stay	✗	✓	✗

Table 1. Treatment Summary table.

3. Experimental Results

We start the analysis by exposing an overview of the results (Figure 1) and, for the sake of soundness, we compare the baseline scenario with those of previous literature (Table 2). Figure 1 shows the share of subjects who made the optimal decision in each treatment.

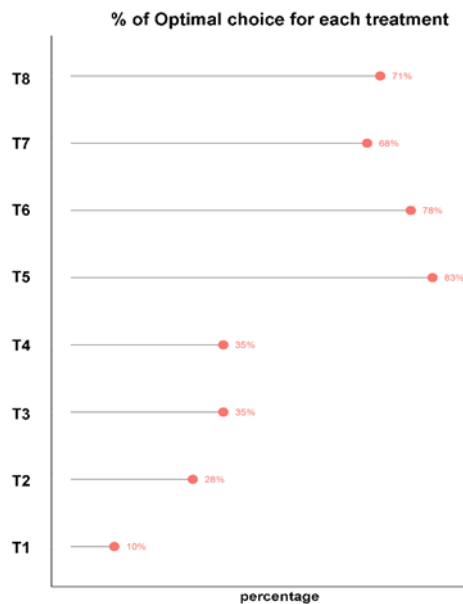


Figure 1. Percentage of optimal choice per treatment.

As it can be observed, there are interesting differences across all the eight treatments. To grasp the size and

the effect of removing each one of the three biases which could explain the irrational choice of subjects, it is useful to analyze the difference between performances comparing paired treatments. Moreover, to get clearer information from the data, it would be better to group the treatments into two categories, each according to the same optimal strategy for the treatments inside the group. For this reason, we compare the results within the first four treatments grouped (T1, T2, T3, and T4), in which the rational choice is to switch and the biases go in the opposite direction of the rational choice, and within the last four treatments grouped as well (T5, T6, T7, and T8). As a general result, comparing the results between both groups, one can see graphically that there exists a big gap between the performance of the first group and the second group. This is because in the first four treatments subjects can maximize their probability of winning if they switch but the biases go in the opposite direction pushing them to stay; hence it is harder for subjects to be right respect to the second group of treatments. In the latter, the decision that maximizes their probability of winning goes in the same direction of the biases.

Starting from T1, the control treatment in which all three biases are present, the share of subjects who took the optimal choice is 10%. This means that 90% of subjects behaved irrationally. It is interesting to compare this result with the results in previous literature. To this purpose, in Table 2 we show the percentage of subjects who decided to switch in the first period across several experiments when the original Monty Hall's treatment has been proposed to participants.⁶

Experiment*	Sample	% of Switching
This experiment	102 non-student subjects from a Mall in Bari	10%
Friedman, 1998	104 students at the University of California, Santa Cruz and Cabrillo Community College	10%
Palacios-Huerta, 2003	217 undergraduate and graduate students in Economics at Brown University	14%
Petrocelli, Harris, 2011	57 undergraduates from Wake Forest University	21%
Franco-Watkins, Derks, Dougherty, 2003	142 undergraduate students of the William & Mary College	22%
Morone, Fiore, 2008	20 students from the University of Bari	35%

Table 2. Observed switching frequency in the previous study.

* Experiments refer to the standard version of the game.

Moving from T1 to T2 we observe an increase of 17.78% ($p\text{-value} = 0.034$) of the percentage of the optimal choice. Hence, we observe an increase of rationality once the Bayesian updating is removed. This positive effect appears also when we take away the illusion of control. Comparing the results between T3 and T1 the 35.23% of subjects took the optimal decision, respect to the 10% in the control treatment T1. The difference

⁶ In the case of repeated games, we report the result of the first period of the experiment in a similar treatment.

of 25.23% (p-value 0.001) is caused by the illusion of control.

Another important aspect that we aim to understand is the impact of eliminating both Bayesian updating and the illusion of control together. This effect is captured taking the difference between the means of T4 and T1, which is 25.44% (p-value 0.0001). Hence removing Bayesian updating and illusion of control together positively and significantly improves the performance of subjects. Since in T2, we isolate Bayesian updating, in T3 the illusion of control bias, and T4 both these biases together, it can be interesting to see whether the effect of removing Bayesian updating (T2) and the illusion of control (T3) one by one is equal or not to the effect of removing both together (T4). To test this difference, we create a third variable made by the sum of T2 and T3, and then we compare the mean of this new cumulative variable with the performance of T4. We reject the null hypothesis (p-value 0.0008), concluding that the Bayesian updating and illusion of control are not cumulative biases. Hence the biases are not additive, meaning that some subjects are affected by Bayesian updating, and others by the illusion of control. It is important to notice that in T4 there is still present the status quo bias, which is harder to detect and to isolate. For this reason, we can assume that the residual of the irrational behavior that is still present, also after eliminating the illusion of control and Bayesian updating, can be attributed to the status quo bias.

We will now analyze the second group of treatments, and we compare the two groups. There are a huge gap and a common pattern between the score of the first four treatments (best strategy switch) and the last four (best strategy stick). This could be mainly explained because the task is easier since there is a double choice, and biases go in the same direction as the right choice of subjects. Comparing T5 with T6 we observe that the impact of the Bayesian updating is negligible (-5.52%) and not statistically significant (p-value 0.400). This happens because in making their decision, subjects already choose two boxes among three, hence it is easier for them to understand the Bayesian dynamic. Thus, keeping or leaving the Bayesian updating does not affect the result if it goes in the same direction of the right choice. Things are different in T7, which is specular to T3, in which we isolate the illusion of control. In this case, the difference between T7 and T5 is -15.52% and highly statistically significant (p-value 0.015). We can conclude that removing the illusion of control negatively affects the subjects' performance. In the last treatment, T8, we eliminate both Bayesian updating and illusion of control together (as we did in T4), and this leads to a statistically significant drop in the percentage of the correct choice respect to T5 (-11.90%, p-value 0.052). Moreover, comparing the differences between T5-T6 and T7-T8 we can assess the impact of Bayesian updating in this group of treatments. Previously we stressed that Bayesian updating does not play an important role in this group of treatments, because the difference between T5 and T6, -5.52% (p-value 0.40), is not statistically significant. This result is confirmed by looking at the difference between T7 and T8 because the performance varies practically for the same size, -5.39% (p-value 0.819), which in turn is not statistically significant.

All in all, we propose a logit regression model to (i) summarize the results outlined in figure 1 and (ii) to control the effects of age, gender, education, and employment status. Table 3 reports a logit regression model in the reduced form, considering only the average treatment effect and in the complete form, including the

aforementioned socio-demographic characteristics. We also report the marginal effects to enhance the interpretability of the results.

Dependent Variable= optimal choice		Reduced Form		Complete Form	
Regressors	Coefficient	Marginal Effects		Coefficient	Marginal Effects
Constant	-2.197 (0.372)***			-2.144 (0.688)***	
T2	1.241 (0.456)***	0.177 (0.625)***		1.248 (0.459)***	0.177 (0.063)***
T3	1.588 (0.434)***	0.252 (0.061)***		1.606 (0.434)***	0.253 (0.060)***
T4	1.597 (0.441)***	0.254 (0.063)***		1.614 (0.441)***	0.255 (0.062)***
T5	3.806 (0.462)***	0.733 (0.05)***		3.837 (0.467)***	0.733 (0.051)***
T6	3.486 (0.454)***	0.684 (0.000)****		3.505 (0.457)***	0.682 (0.055)***
T7	2.942 (0.437)***	0.578 (0.060)***		2.971 (0.435)***	0.579 (0.059)***
T8	3.112 (0.439)***	0.614 (0.058)***		3.147 (0.440)***	0.615 (0.057)***
age				-0.065 (0.096)	-0.012 (0.017)
gender: male				-0.206 (0.215)	-0.037 (0.039)
education				0.082 (0.135)	0.015 (0.024)
Self-employed				-0.229 (0.319)	-0.042 (0.058)
housewife				-0.083 (0.283)	-0.015 (0.051)
retired				0.484 (0.385)	0.086 (0.066)
student				-0.396 (0.452)	-0.073 (0.083)
other employment status				-0.262 (0.737)	-0.048 (0.117)
Pseudo R ²		0.203			0.208
Observations		681			681

Table 3. Logit regression with robust standard errors. Note that the marginal effects for factors level are the discrete change from the baseline level. *** refers to p-values<0.001, while other cases report a p-value>0.10. Reference categories include *Treatment 1* in the reduced form and, additionally, *female* and *employed* in the complete one.

As it can be noticed, different level of age, gender, and employment status do not lead to a significant variation in the optimal choice ratio. All the average treatment effects discussed above are confirmed by the regressions performed.

4. Further extensions

In the proposed artefactual field experiment, the selected sample is heterogeneous and considers different population groups. It might be worthy to investigate how different skilled subjects' respond to the proposed dilemma. We repeated the same experiment using an online platform. We administered questionnaires addressing it to specific groups: (i) students (417 participants), (ii) former students (21 participants), and (iii) experts in the economic area (172 participants). An incentivized (a) and a non-incentivized (b) classroom experiment was carried out respectively, while for the third case, a non-incentivized experiment was

administered through the Economic Science Association (ESA) mailing list. At the end of the data collection, for the incentivized (a), one of the students was randomly chosen and he/she won the prize of 10 euros. Figure 2 summarizes the main results.

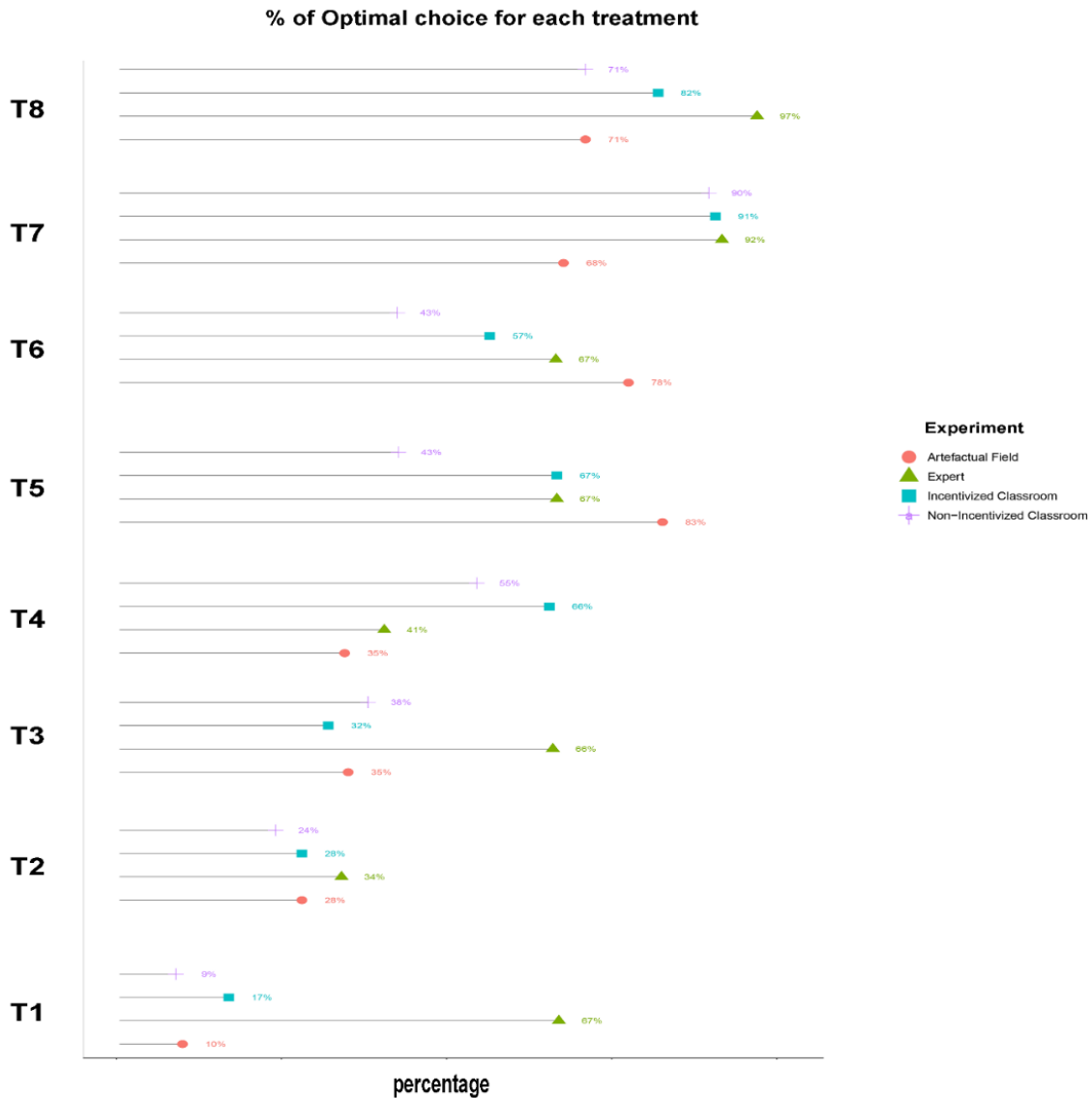


Figure 2. Percentage of optimal choice per treatment and sample type.

Focusing on T1, the control treatment in which all three biases are present, the share of subjects who took the optimal choice was 10% in the artefactual field experiment, in these other experiments we can observe a homogeneous behavior among subjects, except for the expert sample (67%). The percentage of optimal choice is 9% in the non-incentivized experiment, and 17% in the incentivized one. In all the other treatments we cannot observe a significant difference in choosing except for the non-incentivized former students and the expert subjects. The former students show a less understanding of the game, they have a worse percentage of optimal choice per treatment. The experts seem to recognize the Monty Hall problem and its resolution, they choose the optimal choice in both Treatment 1 (67%) and Treatment 3 (67%). This allows us to assume that experts are not affected by the illusion of control but when we remove the Bayesian updating for them is less

easy to recognize the theoretical game. Considering the other treatments, from T5 to T8, we can confirm expert awareness about the game as they identify "stay" as an optimal choice, as well as the ability of the other two groups. Thus, it is easier to recognize the optimal choice when it goes in the same direction as biases.

5. Conclusions

The main goal of our experiment has been to identify and quantify the biases behind the anomalous behavior of people when they deal with the Three Doors dilemma. We provide an artefactual field experiment, carried out in a mall in Bari (Italy), to isolate the different reasons behind the irrational choice of participants. According to the experimental results, we can quantify the size and the impact of three main biases that explain the anomalous behavior of participants: *Bayesian updating*, *illusion of control*, and *status quo bias*.

Our main considerations have been clear: the biases are not additive, meaning that some subjects are affected by Bayesian updating, and others by the illusion of control. As we can see from the results we are not able to isolate and detect the status quo bias (T4 and T8), for this reason, we can assume that the residual of the irrational behavior that is still present, also after eliminating the other two biases, can be attributed to this one. Another important observation is that in the second group of treatments, in which the right decision is to stay, we registered a higher percentage of optimal choice, this is because, subjects already choose two boxes among three, hence it is easier for them to understand the Bayesian dynamic. Thus, keeping or leaving the Bayesian updating does not affect the result if it goes in the same direction of the right choice.

Testing this anomalous behavior of people when they deal with the Monty Hall dilemma, we wanted to verify if sociodemographic aspects could have some effects on the subjects' decisions. We can affirm that different levels of age, gender, and employment status do not lead to a significant variation in the optimal choice ratio.

To conclude we investigated how different skilled subjects respond to the proposed dilemma. We repeated the experiment addressing it to three different groups: experts, incentivized, and non-incentivized students. From the results emerge two important aspects. Experts know the game and make the right decision, even if when the treatment is not the traditional ones, they can reconnect it with the theoretical game. Thus, it allows us to suppose that they are not affected by the illusion of control bias. The other important aspect is that non-incentivized students perform worse in almost all the treatments compared to the other groups.

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Annex

1) Questionnaire administer during the artefactual field experiment:

1. ETÀ

☐ 18 – 29 ☐ 30 – 37 ☐ 38 – 49 ☐ 50 – 64 ☐ 65+

2. SESSO

☐ M ☐ F ☐ ALTRO _____

3. COMUNE DI RESIDENZA: _____ **CAP** _____

4. COMPONENTI NUCLEO FAMILIARE

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5+

5. TITOLO DI STUDIO

- ☐ LICENZA DI SCUOLA ELEMENTARE
- ☐ LICENZA DI SCUOLA MEDIA
- ☐ DIPLOMA
- ☐ LAUREA E POST-LAUREA

6. PROFESSIONE

- ☐ STUDENTE
- ☐ DISOCCUPATA/O
- ☐ CASALINGA/O
- ☐ LAVORATORE DIPENDENTE
- ☐ LAVORATORE AUTONOMO
- ☐ PENSIONATA/O
- ☐ ALTRO _____

7. MONTY HALL

TRATTAMENTO	SCELTA			CAMBIO			OUTPUT	
	SI	NO		SI	NO		BUONO: €	
	A	B	C	A	B	C	SI	NO