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Heuristics and Biases in Travel Mode Choice[1]

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Abstract

This study applies experimental methods to analyze travel mode choice. Two different scenarios are considered. In the first scenario, subjects have to decide whether to commute by car or by metro. Metro costs are fixed, while car costs are uncertain and determined by the joint effect of casual events and traffic congestion. In the second scenario, subjects have to decide whether to travel by car or by bus, both modes in which costs are determined by the combination of chance and congestion. Subjects receive feedback information on the actual travel times of both modes. We find that individuals exhibit a marked preference for cars, are inclined to confirm their first choice and demonstrate travel mode stickiness. We conclude that travel mode choice is subject to heuristics and biases that lead to robust deviations from rational choice.

JEL Codes: C91, D83, R41, R48.

Keywords: travel mode choice, learning, information, heuristics, cognitive biases.

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Introduction

A rational approach to travel mode choice assumes that travelers make decisions by choosing the optimal combination of travel costs and travel times (Becker 1965, Mirchandani and Soroush 1987, Cascetta 1989, Friesz et al. 1994). This model implies that individuals correctly process all the available information and are not affected by cognitive biases. In contrast, non-standard theories of decision-making under uncertainty depart from strict definitions of rationality, especially when decision-makers face repeated choices (Starmer 2000). In this setting, behavioural models introduce a great variety of assumptions regarding information processing and learning, based on findings derived from the field and the laboratory. In particular, psychological studies indicate that decision makers are boundedly rational, use choice heuristics and are affected by perceptual and cognitive biases.

This experimental study is intended to test the validity of the rational approach to choice of travel mode and to investigate the reasons which lead to sub-optimal choices. The design consists of two scenarios. In the first, subjects choose repeatedly between car and metro. Metro travel costs are fixed, while car costs are uncertain and determined by the joint effect of casual events and traffic congestion. In the second scenario, subjects choose repeatedly between car and bus, both modes in which costs are determined by the combination of casual events and traffic congestion. Traffic congestion is determined by the percentage of commuters choosing the same mode. Casual events are determined by independent drawings from a probability distribution unknown to the subjects. We inform subjects of the travel times achieved in both available modes to study how they form and adjust expectations regarding travel time.

The paper is divided into five sections. Behavioural research on travel mode choice is summarized in section 2. Section 3 illustrates hypotheses and experimental design. Results and implications are discussed in section 4. Section 5 draws some conclusions.

2. Background literature

Becker's (1965) approach to travel mode choice assumes that rational travelers optimize the production function of travelling by choosing the optimal combination of monetary costs and expected times. This choice is determined by minimizing total travel cost, which is the sum of direct costs (travel mode price) and indirect cost (time expressed by monetary units). Each traveler holds a subjective belief about travel times based on prior experience and on public information. When the choice is repeated, this belief is updated in a Bayesian manner on the basis of actual travel time. Thus, a sequence of choices is rational if it converges with the mode associated with the lower total cost.

Empirical and laboratory research provides abundant evidence that individuals violate the assumptions of rational decision theory when travel times are uncertain. Behavioural research on the determinants of travel mode choice focuses on three main areas: the mechanisms of information processing and learning, the impact of habit on commuters' decisions, and the effect of travelers' risk attitude.

Some evidence relevant to travel mode is provided by the study of route choice, which is the subject of a larger amount of empirical and experimental work. Both route choice and travel mode choice take the form of coordination games in which rational players should coordinate on an equilibrium. The payoff each player can achieve is conditional on her/his ability to diverge from or to converge with other players' choices. This process depends strictly on the expectations of the choices made by others, which are formed on the basis of prior experience and public information. Evidence from the field and from the laboratory supports the notion that the activities of information collecting and processing are heterogeneous across individuals and are affected by cognitive biases, which limit the rationality of choices.

A first source of distortion derives from the fact that the variability of travel times is perceived as less than it really is because it is inferred by actual times. Since sample data are biased estimates of population distribution, travelers' subjective perception may result as different from real values. According to representativeness heuristics (Kahneman and Tversky 1973), variability of experienced travel times is used to assess the real variance in travel times and this estimate is consequently lower than the real values (Kareev et al. 2002). Empirical research (Srinivasan and Mahamassani 1999, Jong at al. 2003, Abdel Aty and Abdallah 2004) shows that information on timetables or travel delays is often inaccurately processed by stressing some types of messages over others and that real time information is collected and processed sequentially and not instantaneously or exhaustively. Ben-Elia et al. (2008) analyse the combined effect of personal experience and real time information on travelers' route choice and conclude that there is substitution, rather than complementarity, between the two. Their key finding is that information is better processed when travelers lack long-term experience regarding travel time distribution. These results have negative implications for transportation policies, which increasingly rely on the fact that travelers are provided with real-time travel information which is more comprehensive and accurate than information based only on personal experience.[2] Travelers' rationality may also be impaired by limited memory, as documented by psychological research on working-memory capacity. Even if travelers adhere to the principle of payoff maximization, their incapacity to take into account all previous travel costs leads to a failure to correctly compute the best rational strategy. Kareev et al. (1997) provide evidence that the individual differences in working-memory capacity imply that decision-makers process samples of different sizes and hold different subjective expectations.

The fact the travel choices are mostly repeated choices also negatively affects travelers' rationality (Gärling 1998). Habit triggers an automatic reaction to external inputs that is not based on detailed deliberation (Aarts et al. 1997). Mahmassani's (1996) survey on the behaviour of commuters points out that they are guided mainly by heuristic reasoning. Mahmassani and Liu (1998) propose a list of behavioural strategies followed by commuters in route switching decisions and associate them with information provided on delays and departures. Other empirical studies (Verplanken et al. 1994, Verplanken and Aarts 1999) confirm this view by showing that if habitual behaviour increases in strength, mental and cognitive efforts are reduced to a minimum and additional information is scrutinized less. In a simulation model on route choice, Nakayama and Kitamura (2000) show that driver-network systems do not converge to equilibrium when these behavioural properties are assumed. The results of their simulations are that network systems do not necessarily converge to equilibrium and that drivers develop the habit of choosing the same route repeatedly.

[2] This evolution is due to the increasing use of ATIS (Advanced Traveler Information Systems) technologies, such as broadcast traffic conditions, Variable Message Signs (VMS) and cellular information systems.

This tendency is even more pronounced in mode choice. Cars are generally perceived as the means of travel which gives people a sense of comfort, independence and control. The costs associated with car are frequently undervalued because they are not paid entirely simultaneously with car use.[3] These factors explain the presence of a general propensity to use private cars and a psychological resistance to reducing it (Van Vugt et al. 1995, Tertoolen et al. 1998, Hensher 2001, Steg et al. 2001, Bamberg et al. 2003, Anable and Gatersleben 2004). This view is further corroborated by the fact that mode choices are strongly dependent on subjective determinants (Scheiner and Holz-Rau 2007, Johannson et al. 2006). Individual life styles and differences in people's attitudes and personality traits play such an important role that they represent a key problem in the implementation of effective transportation policies.

Finally, the uncertainty characterizing travelers' choice makes risk propensity a key variable. Empirical work supports the hypothesis that travelers are usually risk adverse (Abdel-Aty and Abdallah 2004). This assumption is analyzed in an experiment on route choice by Katsikopoulos et al. (2000), who use a simulating device to investigate drivers' behaviour. In their design, subjects choose between a reference route, whose travel time is certain, and some alternative routes, to which a range of travel times are associated. Two scenarios are compared. In the first scenario, related to the domain of gains, the alternative route has an expected time travel shorter than the reference route, while in the second scenario, related to the domain of losses, the expected travel time of the alternative route is longer than the reference one. Subjects exhibit risk aversion for gains and a risk prone attitude for losses. Further evidence supporting this theory is provided by Ben-Elia et al. (2008) who show that better information increases risk seeking behaviour, reduces initial exploration and increases heterogeneity of choices. In the context of route choice, in a laboratory context Avineri and Prashker (2006) show that to provide travelers with more accurate information on actual travel times does not necessarily increase their propensity to choose faster routes. This is explained by the *payoff variability effect*, according to which the increase of travel time variability makes choices more heterogeneous and significantly reduces the maximization rate.

3. Experimental setup and hypotheses

Our experiment was carried out in the spring of 2008 at the University of Florence. We submitted travel mode choices to 62 undergraduate students from the Faculties of Economics and Political Sciences. The test was computerized using a modified version of the Z-tree software (Fischbacher 2007). Each subject was given a show-up fee of 5 Euros. At the start of each session subjects received an endowment of 150 experiment tokens and written instructions, which were read aloud by the monitor.[4] At the end of the session, subjects were paid privately in cash according to the tokens they held. The experiment tokens were converted into euro at a pre-established rate made known to subjects before the test. Average earnings were 18.4 Euro, including the show-up fee.

We ran three treatments with different groups of subjects. The between-subjects design was adopted to avoid carryover effects from one treatment to the other. In the

[3] Car costs are daily direct costs such as fuel, parking fees, parking, as well as indirect costs such as usage of tires, maintenance, etc. Moreover, external factors such as pollution or social costs due to car accidents are not easily computable and often neglected.

[4] Prior to the start of the experiment, participants had the opportunity to become familiar with the design in three unpaid test rounds. Before and after these rounds, subjects could ask aloud questions regarding the experiment procedures.

first treatment, which was built on two sessions, subjects had to choose between car and metro, in the other two treatments between car and bus. The second and third treatments were differentiated only by the fixed cost of the bus, which decreased from 1.0 to 0.8 in order to isolate *ceteris paribus* the effect of a bus price reduction

Table 1 summarizes the experimental design by showing the number and gender of participants for each treatment and session.

Table 1 Number and gender of participants by sessions

Session	Treatment	Participants (female + male)
1	Metro vs. Car	15 (8 + 7)
2	Metro vs. Car	15 (7 + 8)
3	Bus 1.0 vs. Car	15 (7 + 8)
4	Bus 0.8 vs. Car	17 (9 + 8)
Total		62 (31 + 31)

In each session, subjects were to choose a travel mode for 50 rounds. For each travel mode they were informed of monetary costs and of scheduled travel time. It was also made clear that any deviation from the scheduled travel time was associated with a monetary cost or gain.

Before choosing, subjects received the following information:

a) the scheduled travel time for each mode;
b) that metro travel time was fixed, whereas car and bus travel time were uncertain and depended on traffic congestion, as determined by the combined choices of all the subjects, and on some casual factors (weather, car accidents, road works), whose effects on travel time were randomly chosen by the computer before each round according to a fixed probability distribution, unknown to the subjects;
c) the fixed cost of each mode;
d) the penalty to be paid or the reward gained (0.5 experimental token) respectively for each five minutes of delay or for each five minutes in advance of the scheduled travel time.

The experimental parameters made known to subjects are shown in Table 2.

Table 2 Scheduled and expected travel times and travel costs

Treatment	Car Expected Travel Time (in minutes)	Car Fixed Cost* (in tokens)	Metro Scheduled (fixed) or Bus Scheduled (expected) Travel Time (in minutes)	Metro / Bus Fixed Cost* (in tokens)
Metro vs. Car	25	1.5	30	1.0
Bus 1.0 vs. Car	27	1.5	32	1.0
Bus 0.8 vs. Car	27	1.5	32	0.8

* Metro total cost was equal to the fixed cost, while bus and car travel total costs also depended on traffic congestion and casual factors.

In each round, after making their choice each subject was privately informed of:

a) the travel time achieved by both available modes;
b) the level of traffic congestion defined as *moderate*, *intense* or *chaotic*, related to the percentage of subjects choosing the car;
c) the individual total cost in tokens of the travel, given by the sum of fixed cost and of eventual penalties or rewards;
d) the remaining number of tokens.

To test how expectations on travel time were formed and adjusted, the parameters of the probability distributions which determined the effect of casual factors and traffic congestion on travel times was kept unknown to subjects.

In the metro treatment, the effect of casual factors on car travel time depended on a random selection from the probability distribution of Table 3.

Table 3 The effect of casual factors on car travel time - Metro treatment

	Car Travel Time				
Travel Time (in minutes)	20	25	30	35	40
Probabilities	45%	30%	10%	10%	5%

The expected value of the distribution is twenty-five minutes, which was the average car time made known to subjects. For each five minutes of delay (or ahead of time) with respect to this average value, car cost was increased (or decreased) by 0.5 tokens.

Car travel time was also dependent on traffic congestion,[5] as shown in Table 4.

Table 4 The effect of traffic congestion on car travel time – Metro and Bus treatments

	Level of traffic congestion		
	moderate	intense	chaotic
Share of car users	≤ 55%	> 55% ≤ 75%	> 75%
Car travel time variation (in minutes)	0	+5	+10

If the share of car users was not greater than 55%, car travel time was equal to that randomly drawn from the distribution of Table 3. If the share was between 55% and 75%, car travel time was increased by five minutes and, consequently, the total cost was increased by 0.5 tokens, while if the share was over 75%, car travel time was increased by ten minutes and total cost by 1.0 token. Thus, if the percentage of car users was lower than or equal to 55%, car expected travel time was twenty-five minutes and car expected total cost was equal to 1.0 token. In this case, since subjects were informed that each five minutes of delay (ahead of time) implied a monetary loss (gain) of 0.5 tokens, car expected cost was equivalent to the fixed metro cost of 1.0 token. In this treatment subjects have a 45% chance of achieving a car travel time of 20 minutes, with a gain of 0,5 tokens with respect to the metro choice, but this chance is challenged by the choices of other subjects as traffic congestion can offset or even reverse this gain.

In the bus treatments, the effect of casual factors on car travel time was given by random selection from the distribution of Table 5.

[5] Our hypothesis on traffic congestion introduces a strategic interaction in subjects' choice and sets up a coordination game with asymmetric payoffs.

Table 5 The effect of casual factors on car travel time – Bus treatments

	Car Travel Time				
Travel time (in minutes)	20	25	30	35	40
Probabilities	30%	30%	20%	10%	10%

The expected value of this distribution, made known to subjects, is twenty-seven minutes. As in the metro treatment, any deviation from the scheduled bus time was associated with a penalty (or a reward) of 0.5 tokens for each five minutes of delay (or ahead of time). The impact of traffic congestion on car time was determined as in the metro treatment (Table 4). As in the metro treatment the choice of car offers little potential for gain as it can be hampered by traffic congestion.

Bus travel time was also assumed to be uncertain and dependent on chance and traffic congestion. The effect of casual factors on bus travel time depended on a random draw from the distribution of Table 6.

Table 6 The effect of casual factors on bus travel time – Bus treatments

	Bus Travel Time		
Travel time (in minutes)	30	35	40
Probability	70%	20%	10%

We excluded the possibility that the bus could arrive ahead of the expected time. The expected value of the distribution is thirty-two minutes, which was the scheduled time made known to subjects. For each five minutes of delay with respect to the average value, bus total cost was increased by 0.5 tokens.

The impact of road congestion on bus travel time was assumed to be lower than on car travel time (Table 7), which is the case if the traffic system includes routes and lanes reserved for buses.

Table 7 The effect of traffic congestion on bus travel time – Bus treatments

	Share of Car Users	
	≤ 55%	> 55%
Bus travel time variation (in minutes)	0	+5

If the actual share of car users was not greater than 55%, traffic congestion had no impact on bus travel time that was equal to the value determined by the distribution in Table 6. In this case, in the bus 1.0 treatment the bus total cost was 1 token for an expected travel time of thirty-two minutes, which was equivalent to the car total cost for an expected travel time of twenty-seven minutes. This equivalence did not hold in the bus 0.8 treatment, in which the fixed cost of the bus was decreased to 0.8.

To summarize, total travel costs were as follows:

a) in the metro treatment, the expected total costs of car and metro were equivalent if the share of car users was not greater than 55%;
b) in the bus 1.0 treatment, the expected total costs of car and bus were equivalent if the share of car users was not greater than 55%;
c) in the bus 0.8 treatment, the expected total cost of the bus was 20% lower than car expected total costs if the share of car users was not greater than 55%.

Thus, in the metro and in the bus 1.0 treatments, if the share of car users was greater than 55%, car cost was higher than the cost of the alternative mode. In the bus 0.8 treatment the bus was on average more advantageous than car.

We intended to verify if travelers were rational decision makers in that they minimize total travel costs given the available information. Thus we aimed to test the following hypotheses:

HP. 1: Subjects did not initially have any reason to prefer one travel mode over another. In the first round, subjects chose between travel modes on the basis of the scheduled travel time and fixed costs of Table 2. Cost minimization implies that a subject's choice between car and metro in the metro treatment and between car and bus in the bus 1.0 treatment is indifferent, while they should prefer bus over car in the bus 0.8 treatment.

$${}_1N_{car} = 50\% \quad \text{(metro and bus 1.0 treatments)}$$
$${}_1N_{car} = 0 \quad \text{(bus 0.8 treatment)}$$

where ${}_1N_{car}$ is the share of subjects choosing car in the first round.

HP. 2: After repeating choices, subjects update their expectations in a Bayesian way. With the effect of traffic congestion and the probability distributions determining casual factors, the expected total costs of the two available modes are equalized in the metro and bus 1.0 treatments if the percentage of car users is no greater than 55%, otherwise car is more costly than the alternative mode. In the bus 0.8 treatment bus expected total costs were lower than car costs. Thus,

$${}_tN_{car} \leq 55\% \quad \text{(metro and bus 1.0 treatments)}$$
$${}_tN_{car} = 0 \quad \text{(bus 0.8 treatment).}$$

where ${}_tN_{car}$ is the share of subjects choosing car in rounds subsequent to the first.

4. Results

Findings are discussed in three sections which correspond to the patterns of behaviour exhibited by subjects in the choice of travel mode.

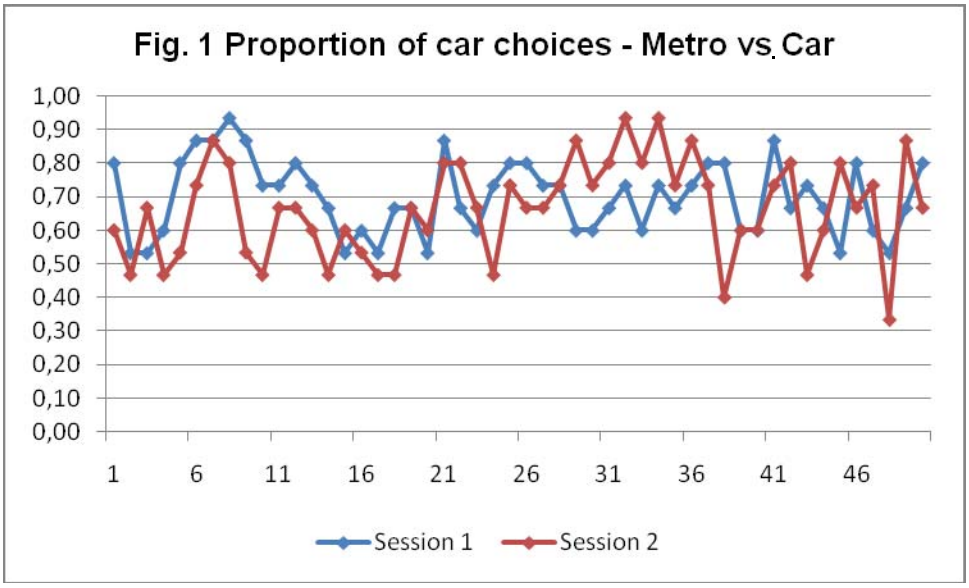
Preference for cars

As discussed in Section 2, empirical studies provide evidence that travelers show a propensity to use private cars over alternative modes. Experimental data support this observation. Table 8 presents the share of car users in all treatments at every fifth round.

Table 8 Proportion of car choices by treatment (every five rounds)

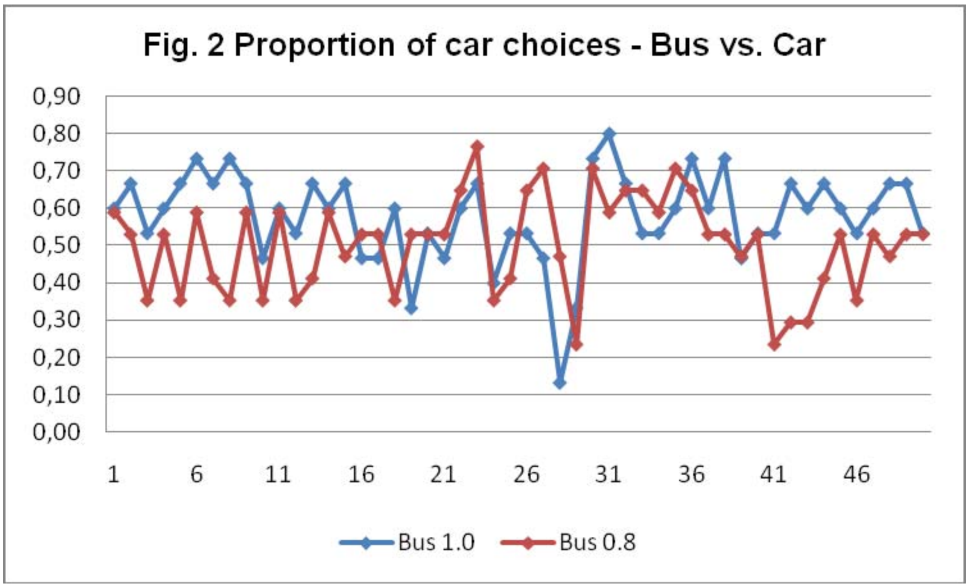
Round	Metro	Bus 1.0	Bus 0.8
1	0.70	0.60	0.59
5	0.67	0.67	0.35
10	0.60	0.47	0.35
15	0.57	0.67	0.47
20	0.57	0.53	0.53
25	0.77	0.53	0.41
30	0.67	0.73	0.71
35	0.70	0.60	0.71
40	0.60	0.53	0.53
45	0.67	0.60	0.53
50	0.73	0.53	0.53
Total	0.68	0.58	0.50

In the metro treatment, the percentage of subjects choosing the car is very rarely lower than 55%, which confirms that car is chosen by the majority of subjects although it is, because of implied traffic congestion, certain to be more costly. Over this percentage, the probability distributions determining the effect of traffic congestion and casual factors indeed confirm that the car expected cost was higher than metro expected cost. Figure 1 shows the share of car users in each round of the two sessions.

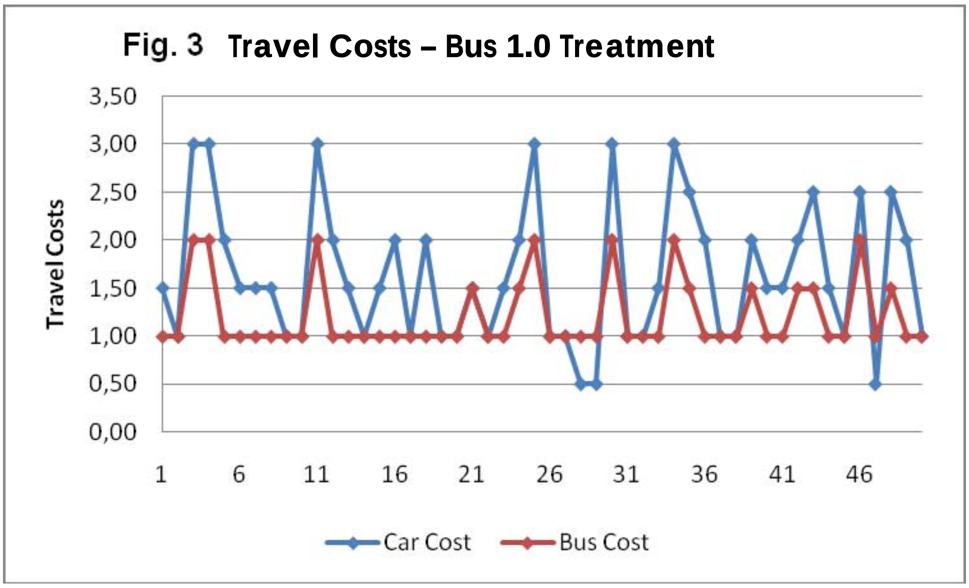


The share of car users is nearly the same in the first and in the last round, although it reaches its peak around the 7th-8th round and then fluctuates around the initial value. This finding appears to be contingent more on behavioural inclinations acquired outside the laboratory than on information acquired in the laboratory. Subjects' choices are dependent on their initial propensity to choose cars rather than on the process of learning. This interpretation is confirmed by looking at actual travel costs, as determined by random selection and by subjects' choices. Although the average car total cost (1.46) is greater than the fixed metro cost (1.00), the ratio between the average shares of car and metro users is nearly two to one.

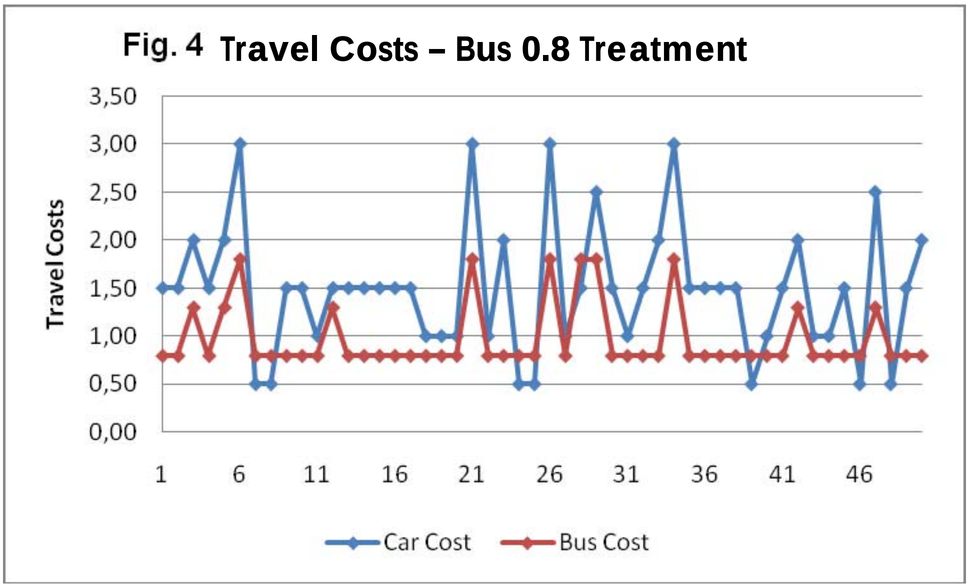
In the bus (1.0) treatment, cars are chosen on average by 58% of the subjects (Table 8). Figure 2 shows the share of car users in each round of the two bus treatments.



In this case too, the equivalence between expected total costs of car and bus remains below the threshold of 55% of car users but this share is exceeded in 40 rounds out of 50. Actual travel costs in the bus 1.0 treatment are shown in Figure 3. On average, car total cost is 1.63, which is 35% greater than bus cost (1.21).



In the bus 0.8 treatment (see Table 8 and Figure 2), the reduction of the fixed bus cost increases the percentage of bus commuters. However, the share of car users is greater than 50% in 30 rounds and on average is exactly 50. Also in this treatment, costs (Figure 4) validate the robustness of car preference, since the actual bus costs (0.96) are considerably lower than car costs (1.48).



The analysis of the evolution of choices confirms the positive inclination towards car usage. After rounds in which car costs are very high, subjects react very quickly, but the deterrent effect does not last long. Table 9 shows the share of car users in rounds following an outlier value for car cost.

Table 9 Share of car users in rounds following very high car costs

Treatment / Session	Round	Car Cost	Share of Car Users
Metro vs. Car - Session 1	34	3.0	0.73
	35	1.5	0.67
	36	1.0	0.73
	37	1.0	0.80
	38	3.0	0.80
	39	2.5	0.60
	40	1.0	0.60
	41	1.0	0.87
Metro vs. Car – Session 2	46	2.5	0.67
	47	2.5	0.73
	48	1.0	0.33
	49	1.5	0.87
Bus 1.0 vs. Car – Session 3	25	3.0	0.53
	26	1.0	0.53
	27	1.0	0.47
	28	0.5	0.13
	29	0.5	0.33
	30	3.0	0.73
Bus 0.8 vs. Car – Session 4	6	3.0	0.59
	7	0.5	0.41
	8	0.5	0.35
	9	1.5	0.59

The percentage of car users returns to the initial value only two or three rounds later. In the sequence of periods 34-41 of Session 1, this pattern of behaviour is particularly evident. After two cost peaks of 3.0 tokens, the share of car users drops immediately, but it goes back to higher levels after just three rounds. Significantly enough, the groups of rounds in Table 9 are drawn from different phases in all the sessions.

Finally, it is noticeable that cars are more often chosen when the alternative travel mode is metro rather than bus ($t = 4.708$, $p < 0.05$ in the bus 1.0 treatment; $t = 7.86$, $p < 0.05$ in the bus 0.8 treatment). Table 10 confirms this finding by showing the proportion of car choices in all rounds according to percentage.

Table 10 Frequencies of rounds by percentages and treatments (all rounds)

Proportion of car users	Car vs. Metro	Car vs. Bus 1.0	Car vs. Bus 0.8
< 0.50	10	10	20
≥0.50 < 0.60	10	11	20
≥0.60 < 0.70	34	23	5
≥0.70 < 0.80	18	5	5
≥0.80 < 0.90	25	1	-
≥ 0.90	3	-	-
Total no. of rounds	100	50	50

In the metro treatment, the share of car users is lower than 0.50 only in 10% of the rounds, while this percentage increases to 20% in the bus 1.0 treatment and to 40% in the bus 0.8 treatment.

One plausible explanation for this result is provided by prospect theory (Kahneman and Tversky 1973). According to this model, in a decision-making framework in which only losses are possible, people exhibit a risk seeking attitude. As discussed earlier, laboratory research supports this theory for route choice (Katsikopoulos et al. 2000). In our experiment, the car is preferred to metro because it is the riskier travel mode, as it has a zero expected gain with respect to metro choice with no traffic congestion and an expected loss with traffic congestion. This propensity would decrease in the bus treatments because both alternative travel modes are uncertain.

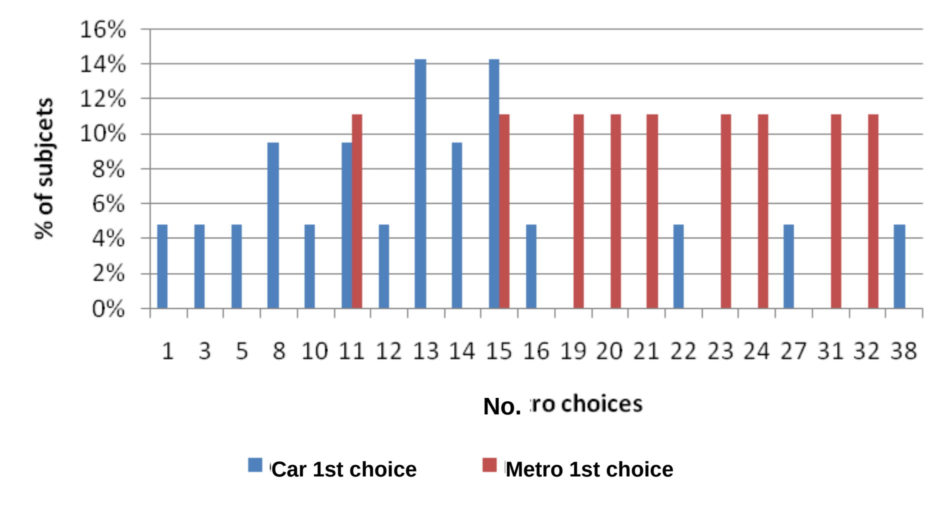
On the whole, these experimental findings provide evidence refuting the rational model of travel mode choice, as defined by Hypotheses 1 and 2. Subjects prefer car to the alternative available mode from the first round. This preference is also confirmed when subjects repeat choices and therefore the probability distributions determining the impact of traffic congestion and casual factors on travel total costs could be learned from experience. We conclude that they do not update expectations on travel costs in a Bayesian way. The reduction of bus fixed cost slightly increased the percentage of bus users but it does not invalidate the result.

The first choice effect

In general Figures 1 and 2 appear to show that the share of car users increases in the second half of each treatment and becomes less erratic in all treatments. Data analysis validates this impression. The average share of car users over all rounds and all treatments is almost the same: it increases from 0.57 in the first 25 rounds to 0.59 in the last 25 rounds, while the standard deviation decreases from 0.180 to 0.145. Moreover, the number of subjects changing travel mode in the last 15 rounds is a third lower than the number switching in the first 15 rounds.

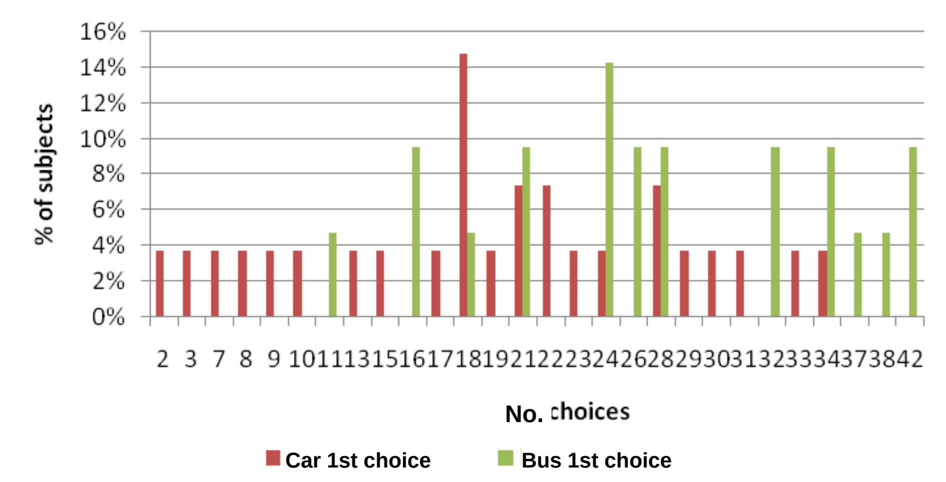
These figures might be interpreted as evidence of learning: subjects would gradually understand the probability distributions determining travel times and this process would decrease choice variability. On the contrary, subjects exhibit a significant tendency to confirm their first choice. Figure 5 shows the distribution of subjects by metro choice, divided into those who choose car and those who choose metro in the first round.

Fig. 5 First choice effect - Metro Treatment



Subjects choosing car in the first round are concentrated on the left of the distribution. 86% of subjects who started by choosing a car chose the metro fewer than 16 times, whereas only 22% of those whose first choice was the metro preferred the metro fewer than 16 times. Over all rounds, subjects who started by choosing a car preferred the metro with a probability of 27% and chose the metro on average 13.8 times, while those who initially chose the metro confirm this preference with a probability of 43% and chose the metro on average 21.7 times. Similar results are shown in Figure 6 for the bus treatments.

Fig. 6 First Choice Effect - Bus Treatments

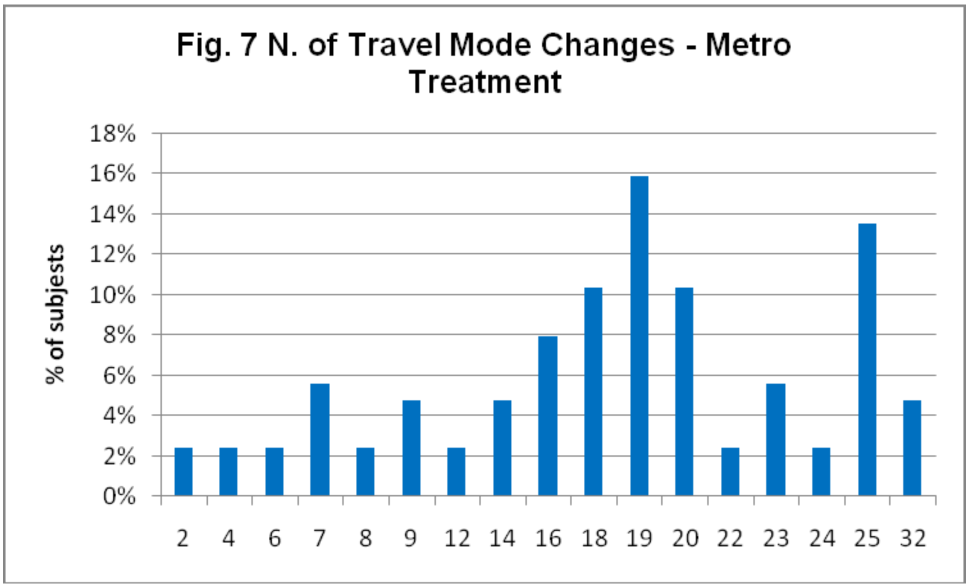


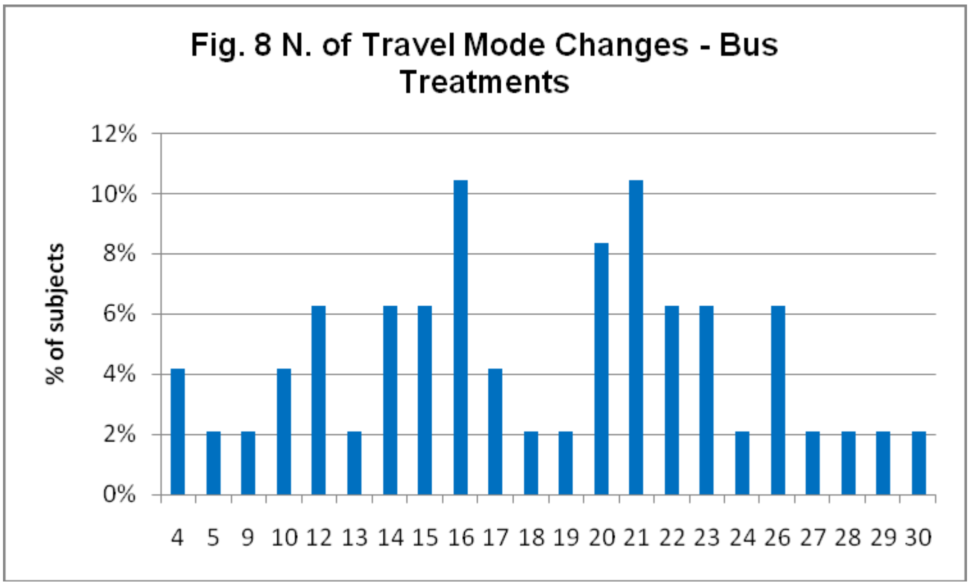
The probability that subjects who chose the bus in the first round will prefer this mode in all rounds is 27%, which is significantly greater than the probability of those choosing the car in the first round (19%). 80% of those whose first choice was the car chose the bus fewer than 28 times compared to 60% of those who exhibited a preference for the bus at the start of the experiment.

The fact that subjects' first choices are reliable indications of their preferences corroborates the proposed interpretation of positive bias towards cars. They seem therefore to apply their real choices in the laboratory context as well, and demonstrate a high probability of sticking to them. The behaviour of subjects depends more on prior experience outside the laboratory than on expected gains in the laboratory. This attitude does in fact seem to conflict with the correct approach to experimentation in economics. A basic tenet of laboratory methodology is that the use of non-professional subjects and of salient monetary incentives will cause subjects to focus their attention on the laboratory setting and render their individual propensities largely irrelevant. In our experiment, this purpose seems to be only partially fulfilled. The explicit reference to travel mode choice reveals that subjects are biased towards one of the alternatives and this preference tends to override the effect of incentives. In effect, travel mode choices are routine decisions, taken over and over again. As discussed in Section 2, they tend to become habitual choices, which cease to be the consequence of a deliberate process of weighing pros and cons. In the laboratory, this attitude is automatically triggered by the cues given to subjects. Once a travel mode has been chosen, goal-directed reasoning plays a limited role in determining decisions, and subjects' decisions are driven by heuristic reasoning. The experimental evidence we collected indicates that the preference for cars and the first choice effect account significantly for subject's behaviour.

Travel mode stickiness

The first choice effect implies that travelers exhibit an aversion to changing travel mode. Figures 7 and 8 present the distribution of subjects according to the number of mode changes.





Only 28.6% of the subjects in the metro treatment and 39% of the subjects in the bus treatments change more than 20 times over 50 rounds. On average, subjects change mode 17.7 times in the metro treatment and 18.0 times in the bus treatments.

Data analysis confirms that changes are negatively correlated with the average travel time in both treatments, although this relationship is not statistically significant. In an experiment on route choice, Selten et al. (2007) provide evidence of the positive relationship between route stickiness and aggregate payoff. They also analyze how travelers react to other commuters' choices by defining two different types of responses. In the first type, called *direct response*, a traveler switches mode in the next round if travel times in the previous round are relatively high. In the second type, the *contrary response*, a traveler changes mode if travel times in the previous round are relatively low, on the basis of the expectation that this mode will attract more travelers in the next round and produce more traffic congestion.

To investigate the occurrence of these responses in the experiment, we define travel mode cost relatively *high* if it is higher than the average travel cost of the previous ten rounds and relatively *low* if it is lower than the average travel cost of the previous ten rounds.[6] In our design, traffic congestion depends only on the share of car users and subjects are given the total travel costs of all modes. Accordingly, we adopt the definitions of *direct* or *contrary responses* given in Table 12.

Table 12 Direct and contrary response modes

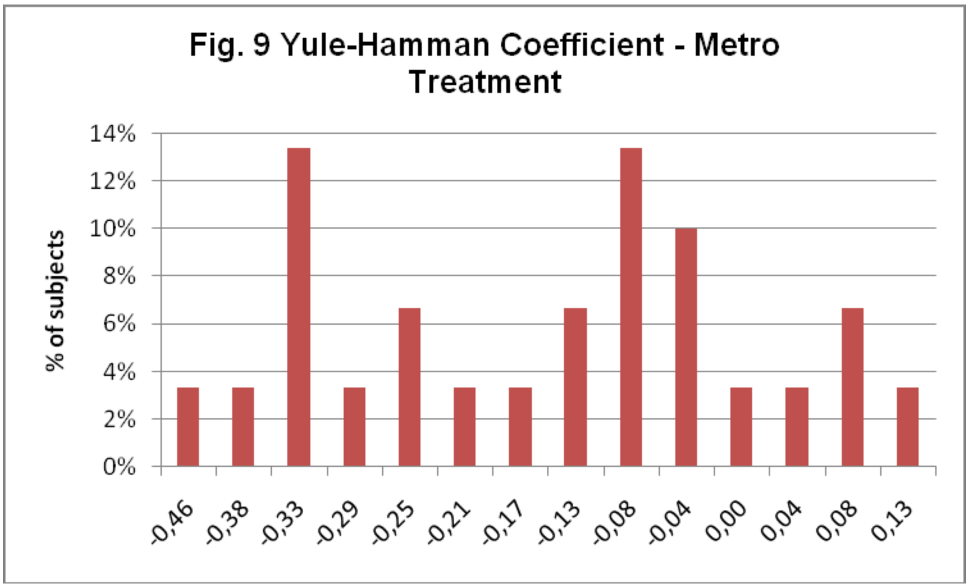
	Travel Costs	
Choices	High	Low
Switching from car to metro/bus	Direct (d1)	Contrary (c1)
Switching from metro/bus to car	Contrary (c1)	Direct (d1)
Confirming car	Contrary (c2)	Direct (d2)
Confirming metro/bus	Direct (d2)	Contrary (c2)

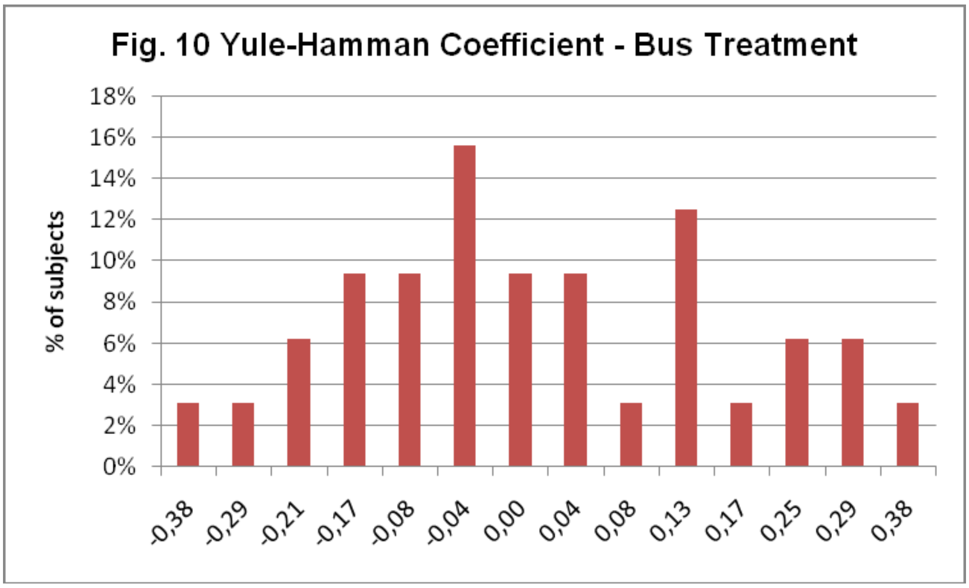
[6] We assume that subjects make their choices on the basis of the previous ten rounds, because we found that the correlation between the number of car users and the average car cost of the previous ten rounds was higher than the correlation with the average car cost of the previous five rounds and of all previous rounds.

For example, in the metro treatment, a change of travel mode is a *direct response* if the subject switches from car to metro upon observing a relatively high car cost or switches from metro to car upon observing a relatively low car cost, while it is a *contrary response* if the subject switches from car to metro upon observing a relatively low car travel cost or switches from metro to car upon observing a relatively high car travel cost. To confirm the metro travel mode over two adjacent rounds is a *direct response* if car costs are relatively high and a *contrary response* if car costs are relatively low. For each subject *i* we calculate the Yule-Hamman coefficient H_i, which is given by:

$$H_i = \frac{\sum_{J=1}^{n} Direct_{ij} - \sum_{j=1}^{n} Contrary_{ij}}{\sum_{J=1}^{n} (Direct_j + Contrary_j)}$$

The coefficient H_i varies between -1 and +1, so that positive values indicate the prevalence of the direct response mode, while negative values indicate the prevalence of the contrary response mode. If values are concentrated around zero, neither mode prevails over the other. Figures 9 and 10 show the H coefficient for all subjects in the metro and in the bus treatments, respectively.





In both distributions the coefficient is mostly concentrated around zero. It varies between -0.46 and +0.13 in the metro treatment and between ±0.38 in the bus treatments. According to the classification proposed by Selten et al. (2007), no subject in the experiment can be classified as a *direct* or *contrary responder*, which is the case if Yule-Hamman coefficients are, respectively, lower than -0.5 and greater than +0.5. An interpretation for this result is that the first choice effect decreases the tendency to change travel mode. The propensity to travel mode stickiness is further corroborated by the fact that subjects in the middle range of the distributions of Figures 9 and 10 on average change travel mode less than those in the extreme quartiles. This confirms our experimental finding that subjects' behaviour is more strictly related to prior learning outside the laboratory than to experience acquired during the experiment.

5. Conclusions

This study provides laboratory evidence that the choice of travel mode is significantly affected by heuristics and biases that lead to robust deviations from rational behaviour. We find that subjects choose modes using behavioural rules that do not necessarily involve the minimization of travel total costs. In particular, travelers exhibit a marked preference for cars, are inclined to confirm their first choice and to travel mode stickiness. These findings confirm that in repeated travel mode choices available information is not properly processed, cognitive efforts are generally low and rational and deliberate calculation play a limited role.

These results have relevant implications for the design of transportation policies. Travel mode choices are determined by a variety of psychological factors and subjective attitudes, such as habit, mode stickiness and limited memory, which should be analyzed and taken into account in improving the efficiency of transportation networks. In particular, the habit of using cars should be assumed to be resistant to the effect of economic incentives. Consequently, little progress can be expected by asking travelers to voluntarily reduce the use of a car or even by subsidizing public transport costs. Transportation policies should aim at changing the individual cognitive perception of the travel mode not only by adopting a range of low intensity tactics (such as progressive increases in fuel costs, additional taxes, parking fees), which may be ineffective, but by initiatives which will increase individual awareness in making choices. The findings therefore reveal that the effect of economic incentives may be overridden by casual factors and subjective attitudes. This observation can also lead to some radical conclusions favouring the use of "command and control" policies, such as limitation of car use (for example limited traffic zones or restrictions applied according to number plate sequence), where no incentives are sufficiently effective in provoking a change of behaviour to achieve goals.

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Appendix

Instructions (translated from Italian)
Metro vs. Car Treatment

WELCOME TO THE LABORATORY

This is an experiment on decision-making in economics. IRPET (The Regional Institute for Economic Planning in Tuscany) and the University of Siena have provided funds to conduct this research.

Each of you will receive a participation fee of 5 Euros for agreeing to take part in this exercise. Depending on your investment decisions, you can earn additional funds. You will need to follow a set of instructions in order to make your decisions. The experiment is an individual experience. Both your choices and your profits will be confidential to all except you. The final payment will be made immediately after the experiment. The payment amount is automatically compiled at the end of the experiment. You are invited to verify your information at the end of the experiment with your initials.

This experiment will produce best results if you respond to it individually without consulting other participants for its duration.

You will be allowed to ask questions after we have reviewed this documentation with you and/or just before you begin the experiment.

You will have trial sessions to hone your decision making skills before the experiment begins.

If you are ready, follow the experiment instructions given below.

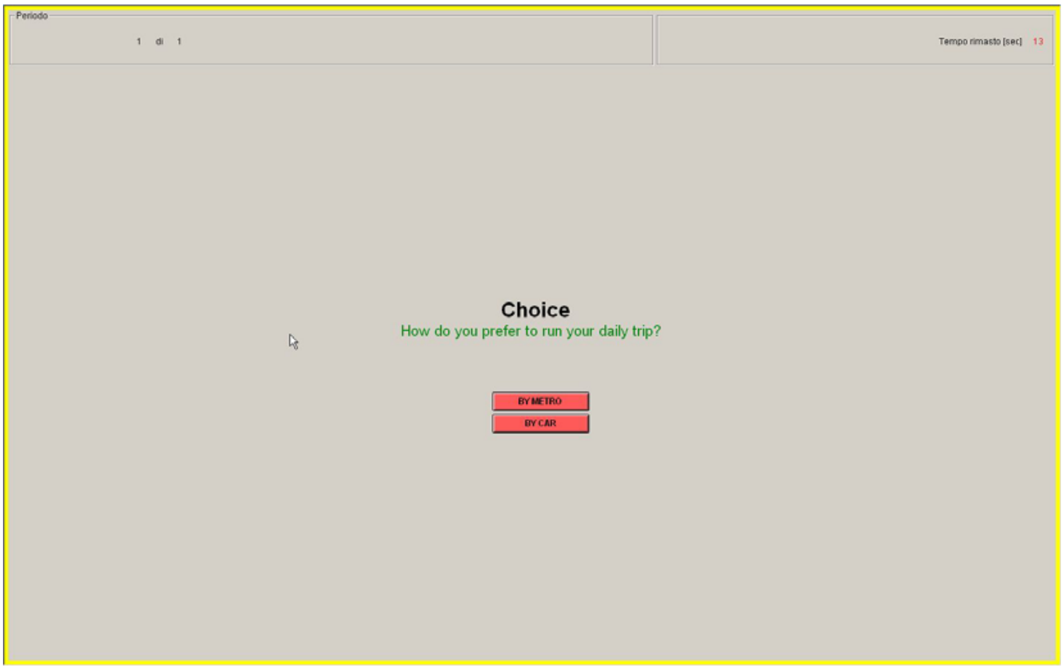
INSTRUCTIONS

The decision that each of you will make is to choose a travel mode. Two modes are available: metro and car. Metro travel time is fixed and equal to 30 minutes, while car travel time is uncertain and on average equal to 25 minutes. After making your choice, you will be informed of the actual time and cost of both modes. If you choose the metro, travel time will always be equal to 30 minutes and travel cost will be equal to 1 unit. If you choose the car, travel time and costs will be variable and determined by two factors:

1) casual factors (weather, car accidents, road works), whose effect on car travel time will be randomly chosen by the computer before each round;
2) traffic congestion, as determined by the travel mode choices made by all participants.

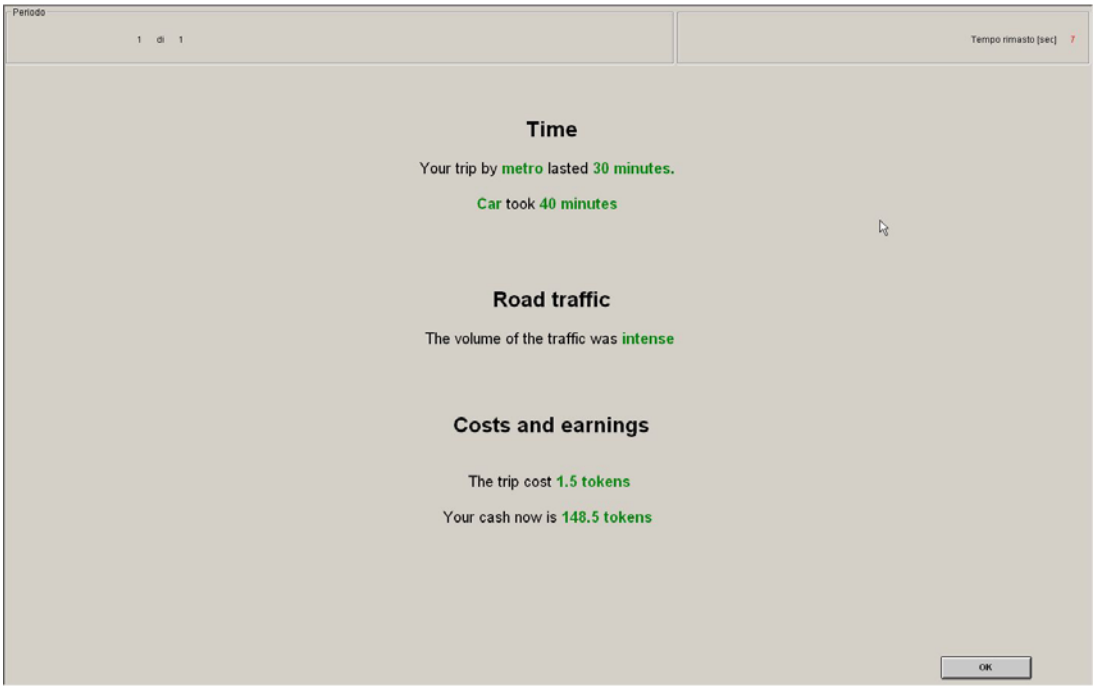
The base car cost is equal to 1.5 units, but if actual car travel time is different from the scheduled time of 30 minutes, you will pay a penalty of 0.5 units for each five minutes of delay or you will gain a reward of 0.5 units for each five minutes in advance of the scheduled time travel.

The experiment will start when the following window appears on your computer screen.

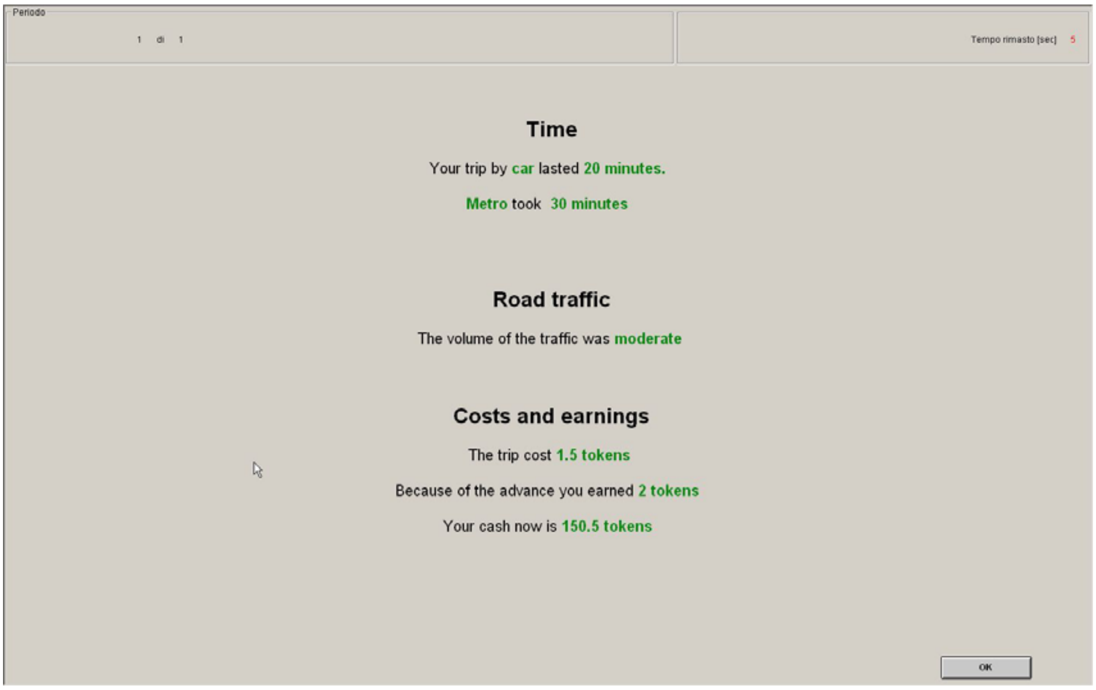


You are required to choose one of the two travel modes by clicking on the appropriate box. The time available to take this decision is shown in the upper right corner of the window. If the time expires without any decision, the computer will select the travel mode time randomly for you.

After all travelers have made their choices, if you have chosen the metro, the following window will appear (the numbers below are exemplificative):



If you have chosen car, the following window will appear on your screen (the numbers below are exemplificative)



As you see, in the window you will find:

a) the actual travel time of both travel modes;

b) the level of traffic congestion defined as *moderate*, *intense* or *chaotic*, related to the percentage of participants choosing car;

c) the monetary payment for the travel (including additional penalties or rewards) and your remaining number of units.

To move to the next round, you will click OK after you have read your results.

You are required to repeat the same travel mode choice for 50 rounds. In each round the procedure will be the same. Travel costs will be paid from the endowment of 150 units that each participant will receive at the beginning of the experiment. Your final overall revenue is the amount of units held at the end of the 50 rounds, which will be translated to real Euros using a rate of:

1 profit unit = 0.1 euro

Thus, the more units you have at the end of the 50 rounds, the greater your final profit will be.

If you need additional information, now is a good time to ask. Once you begin the experiment you cannot stop for information or clarification.

Before the experiment begins you are given trial sessions to practice with your allocation. Any profits obtained during these trial sessions are not included in your total profits for this experiment.

Any questions?

Thank you for your participation. Your time is appreciated.

*****

Bus vs. Car Treatment

WELCOME TO THE LABORATORY

This is an experiment on decision-making in economics. IRPET (The Regional Institute for Economic Planning in Tuscany) and the University of Siena have provided funds to conduct this research.

Each of you will receive a participation fee of 5 Euros for agreeing to take part in this exercise. Depending on your investment decisions, you can earn additional funds. You will need to follow a set of instructions in order to make your decisions. The experiment is an individual experience. Both your choices and your profits will be confidential to all except you. The final payment will be made immediately after the experiment. The payment amount is automatically compiled at the end of the experiment. You are invited to verify your information at the end of the experiment with your initials.

This experiment will produce best results if you respond to it individually without consulting other participants for its duration.

You will be allowed to ask questions after we have reviewed this documentation with you and/or just before you begin the experiment.

You will have trial sessions to hone your decision making skills before the actual experiment begins.

If you are ready, follow the experiment instructions given below.

INSTRUCTIONS

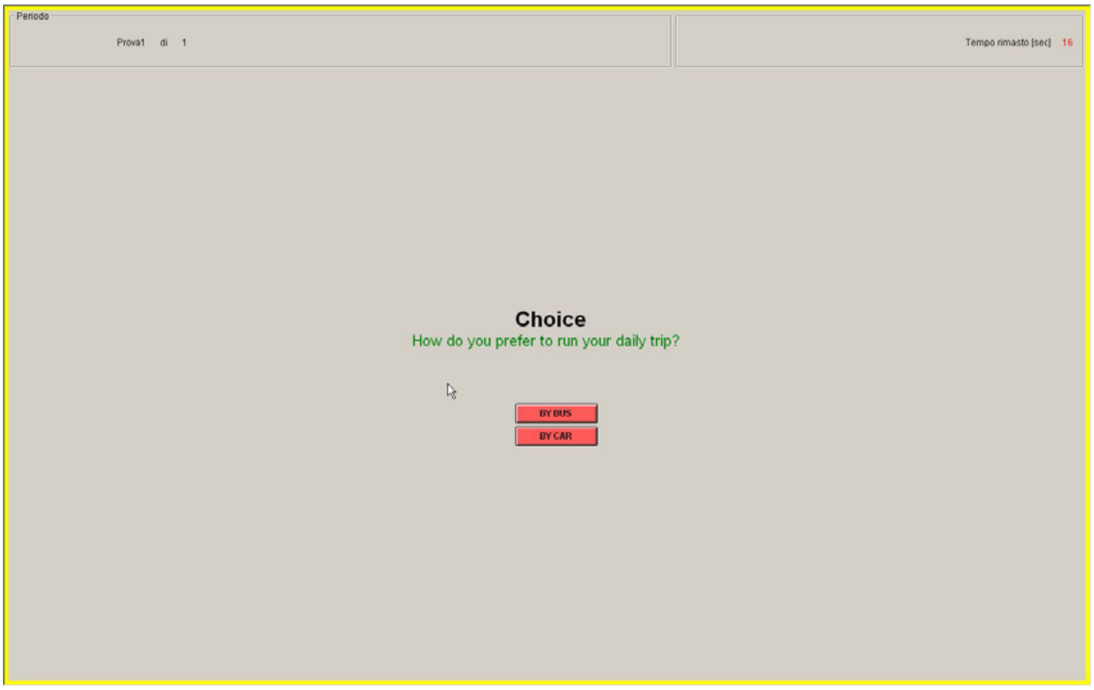
The decision that each of you will make is to choose a travel mode. Two modes are available: bus and car. Bus scheduled and expected travel time is equal to 32 minutes, while car expected travel time is equal to 27 minutes, but actual bus and car travel times are uncertain. After making your choice, you will be informed of time and cost for both modes. Actual travel time and costs for both bus and car are variable and determined by two factors:

1) casual factors (weather, car accidents, road works), whose effect on car travel time will be randomly chosen by the computer before each round;
2) traffic congestion, as determined by the travel mode choices made by all participants.

The base bus cost is equal to 1 unit, but if actual bus travel time is longer than the expected 32 minutes, you will pay a penalty of 0.5 units for each five minutes of delay with respect to the scheduled travel time. Bus can never arrive ahead of the scheduled time.

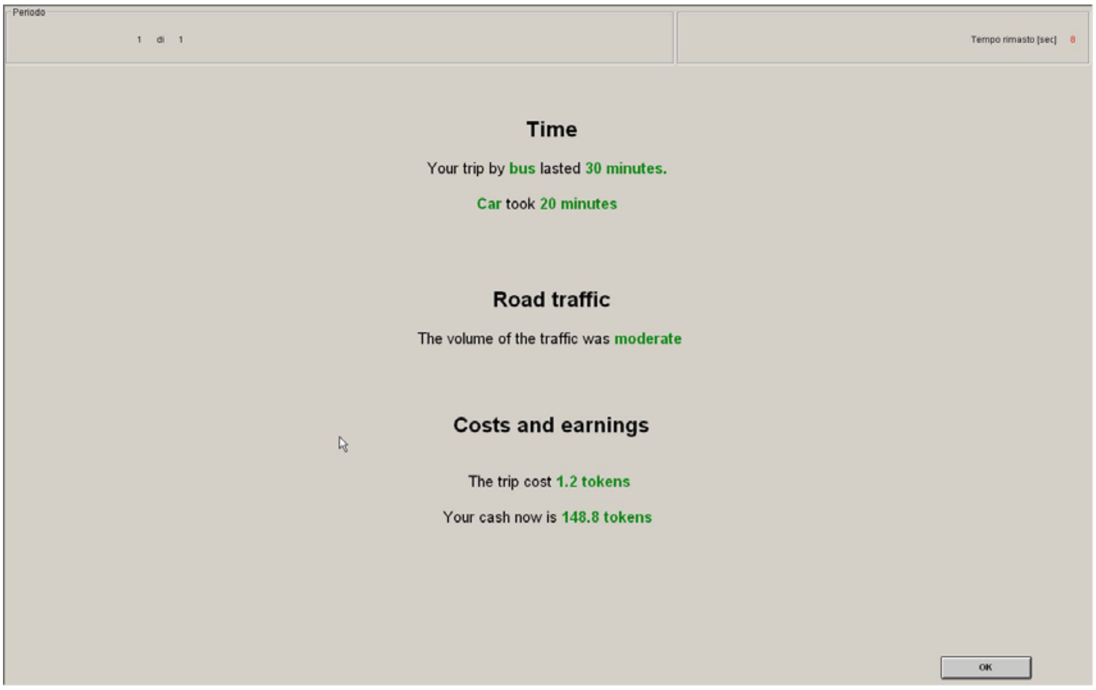
The base car cost is equal to 1.5 units, but if actual car travel time is different from the scheduled time of bus (32 minutes), you will pay a penalty of 0.5 units for each five minutes of delay or you will gain a reward of 0.5 units for each five minutes in advance of the scheduled time.

The experiment will start when the following window appears on your computer screen.

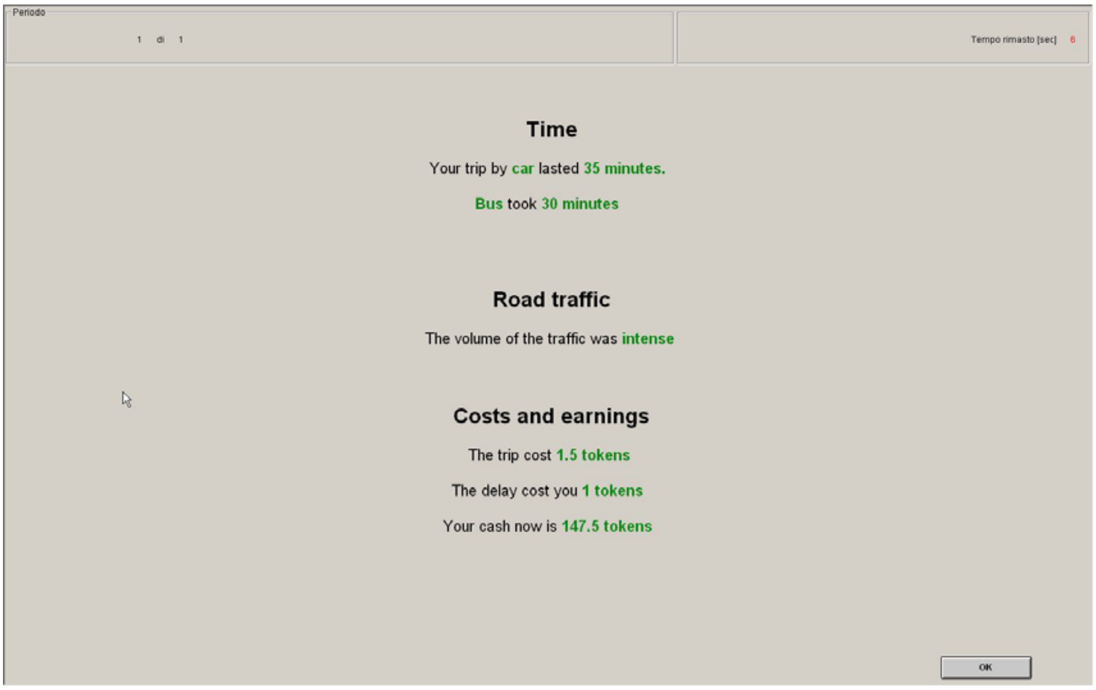


You are required to choose one of the two travel modes by clicking on the appropriate box. The time available to take this decision is shown in the upper right corner of the window. If the time expires without any decision, the computer will select the travel mode time randomly for you.

After all travelers have made their choices, if you have chosen the bus, the following window will appear (the numbers below are exemplificative):



If you have chosen car, the following window will appear on your screen (the numbers below are exemplificative):



As you see, in the window you will find:

a) the actual travel time of both travel modes;
b) the level of traffic congestion defined as *moderate*, *intense* or *chaotic*, related to the percentage of participants choosing car;
c) the monetary cost for the travel (including additional penalties or rewards) and your remaining number of units.

To move to the next round, you will click OK after you have read your results.

You are required to repeat the same travel mode choice for 50 rounds. In each round the procedure will be the same. Travel costs will be paid from the endowment of 150 units that each participant will receive at the beginning of the experiment. Your final overall revenue is the amount of units held at the end of the 50 rounds, which will be translated to real Euros using a rate of:

1 profit unit = 0.1 euro

Thus, the more units you have at the end of the 50 rounds, the greater your final profit will be.

If you need additional information, now is a good time to ask. Once you begin the experiment you cannot stop for information or clarification.

Before the experiment begins you are given trial sessions to practice with your allocation. Any profits obtained during these trial sessions are not included in your total profits for this experiment.

Any questions?

Thank you for your participation. Your time is appreciated.

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