Individual decision-making experiment with risk and intertemporal choice: a replication study

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Abstract: This work aims to study the individual intertemporal decision-making process under risk and uncertainty, by replicating via an online experiment the design proposed by Anderson and Stafford (2009). The structure of questionnaire is the same as the one of the original experiment, in which subjects might choose between two options that differ in resolution time. According to the experimental results, we show that the percentage of subjects choosing later option increases as the value of the later option increases, and the percentage of subjects choosing later option is smaller the longer the temporal delay between the two options. Differently from the original study, we found out that risk does not make subjects less patient and there are interactions between risk and the length temporal delay.

Keywords: Replication; Intertemporal decision-making; Risk; Intertemporal choice; Experiment.
JEL Classification: B40; C91; D8.

On behalf of all authors, the corresponding author states that there is no conflict of interest.

1. Introduction

When deal with individual decision making, economists assume that subjects, or in general *decision-makers*, are rational and, under certain axioms, they make choices according to the alternative that gives them the largest payoff. To compute the payoff, when the alternative is not certain, subjects choose according to the *expected utility theory* because it is assumed that they can compute the exact expected value for each alternative. Thus, when facing a risk, subjects maximize the expected value of some potential payoffs and make their choice according to these computations. However, one may ask himself what happens in case of a subject is supposed to make a choice in which there are several trade-offs to be solved, in terms of both risk and time delay. In this case, when a choice implies a solution to an intertemporal and uncertain problem, another important theory employed in economic models is the Samuelson's *discounted utility theory*. Even though these theories are widely used in economic modelling, it is not sure that they apply also in practice. In fact, in experimental economics theory, several biases lead subjects to do not behave accordingly. There is experimental evidence on the fact that people face the *Allais paradox*, the *gain-loss asymmetry*, the *loss aversion*, the *framing effect*, the *preference reversal*, and other biases that make their behavior not consistent with the theoretical solution when they face risky choices and intertemporal decisions. It is important to study the behavior of decision-makers when they deal with risk and intertemporal uncertainty because experiments can be useful to get evidence on whether agents apply the expected utility theory in evaluating a set of alternatives, and if they make their choice accordingly, in a rational way. According to *Von Neumann and Morgenstern's (1947)* expected utility theory, subjects are rational and always choose the alternative with the largest expected value which maximizes their utility function.[1] When the decision implies an intertemporal choice, Samuelson's discounted utility theory (1937) suggests that individuals choose the alternative with the largest discounted utility. In order understand how individuals' intertemporal decision making is influenced in case of risk presence, we replicate the experimental design by *Lisa R. Anderson and Sarah L. Stafford* (2009) by conducting it online, without monetary incentives. We find that many subjects do not appear to have consistent risk preferences. Despite several consistent results, we found out some different evidence respect to the original paper, such as that risk does not make subjects less patient and that there are significant interactions between risk and the length temporal delay.

This paper is structured as follows: *Section 2* deals with the experimental design; *Section 3* shows the econometric analysis; finally, in *Section 4,* we give some concluding remarks comparing our experimental evidence with the original study.

[1] Von Neumann, J., & Morgenstern, O. (1947). *Theory of games and economic behavior*. Princeton, NJ: Princeton University Press.

2. Experimental design

To replicate the experiment made by Anderson and Stafford (2009), we conducted an online experiment, via *Google Forms*, providing a questionnaire to a sample composed of 1262 university students of law and economics.[2] The survey was published on social networks through two *Instagram* pages: "*Economia del Suicidio"* and "*Giurisprudenza del Suicidio"*, which represent the largest online communities of economics and law students in Italy, respectively. In the questionnaire, each participant is asked to answer 25 pair wise choice questions (participants have to report their preference between option A and option B). Each alternative gives a monetary reward that will be paid in the future, hence it does not give an immediate payoff to the subject. For instance, participants could choice between the two alternatives as follows: *"Option A: receive 20€ in 14 days; Option B: receive 22€ in 28 days".* In this way, we can observe the behavior of people when they deal with intertemporal choices. In option A the date of payment is always earlier than the one provided by option B. At the end of the experiment, one of the 25 scenarios is randomly selected, and subjects are rewarded according to the option chosen in the extracted scenario.[3] If a subject chooses option A for the extracted scenario, the corresponding payoff will be paid on the date indicated in the same option. Especially, we offer a payment delayed by 14 days in option A, while option B will pay the reward in 14 + *n* days. On the factor *n*, hence on the time delay of the payment of option B, we base the three treatments that we run:

- Treatment 1: n=14 days;
- Treatment 2: n=28 days;
- Treatment 3: n=56 days.

We aim to grasp the risk preference of subjects and, in order to capture the presence of anomalous behavior such as inconsistent risk preferences, we insert a measure of uncertainty. To do so, following the original study's experimental design, we employ the *Ellsberg urn.*[4] The urn contains a known amount of balls of different colours, and each colour has attached a value. For instance, one can say that in the urn there are 50 red balls and 50 yellow balls, and if the subject draws a red ball, he would get a payoff equal to 20$, rather if he draws a yellow one, he would get a payoff equal to 24$. This happens for the risky options, which we insert only in some scenarios of each treatment. In the previous example, suppose that the urn is employed to make uncertain the value of option B, the expected value $E(B)$ of the risky option would be computed as:

$$E(B) = 20\$ * 0.5 + 24\$ * 0.5 = 22\$.$$

[2] The data of this study are available upon request.
[3] In this experiment there are not present monetary rewards.
[4] See *Ellsberg, Daniel, "Risk, Ambiguity, and the Savage Axioms." The Quarterly Journal of Economics, vol. 75, no. 4, 1961, pp. 643–669.*

For each treatment (*n)* and period (*t)*, the expected value of option A is equal to 20, and it is always lower than the option B expected value. In this case, one could have: *"Option A: receive 20€ in 14 days, Option B: receive 20€ if a pink ball is drawn (50 out of 100) or receive 24€ if a red ball is drawn (50 out of 100)".* For each risky option, subjects are told both the composition of the urn, that is the number of balls of each colour in the urn and the payment options associated with each coloured ball. A complete set of scenario options used in the experimental treatments is presented in Appendix.

The three treatments (*n)* are structured in the same way: in each of them, for one set of treatments, the payoffs are certain, and for other sets, the payoffs are probabilistic. The *t*=25 scenarios are divided, for each treatment, as shown in table 1.

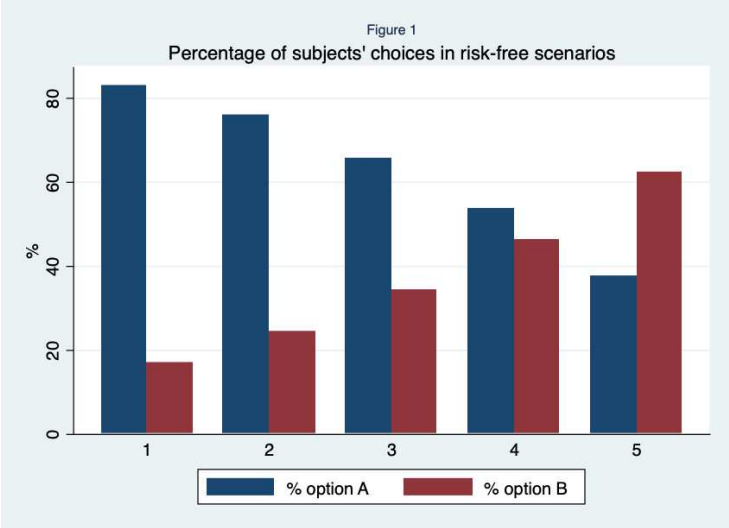
Table 1: Option value for each scenario

Period	**Value Option A**	**Value Option B**
From *t*=1 to *t*=5	Certain	Certain
From *t*=6 to *t*=13	Certain	Uncertain
From *t*=14 to *t*=19	Uncertain	Certain
From *t*=20 to *t*=25	Uncertain	Uncertain

At the end of the questionnaire, subjects are supposed to fill seven sociodemographic questions. Among these, we ask participants whether they are smoker or not. We asked this information since also Anderson and Stafford (2009) did in their experiment, and they found a significant relationship between the status of being smoker and the need to get the sooner payoff. Moreover, differently from the Anderson and Stafford experiment, we do not modify the values of the options, but we keep values equal across the three treatments, maintaining the expected value of B always larger than the one of option A, and inserting the uncertainty of the payoff and the time delay in the way we already shown.

3. Econometric analysis

This section deals with the econometric analysis of the results. We first present the results for certain scenarios, hence from *t*=1 to *t*=5. We consider the first five scenarios in which there are a certain payment of €20 in 2 weeks (option A) and a certain payment of €X in 2weeks + *n* days (option B). As one can see from the figure 1, the percentage of subjects choosing later Option B increases as the value option B increases.



As we expected, when money paid by option B rise, then also the frequency of subjects that report to prefer option B respect to option A increases. However, the number of subjects choosing option B decreases when the time delay between the two options (A and B) increases. This result is visible in table 2, which shows the frequency of subjects who have chosen option A or B in risk-free scenarios.

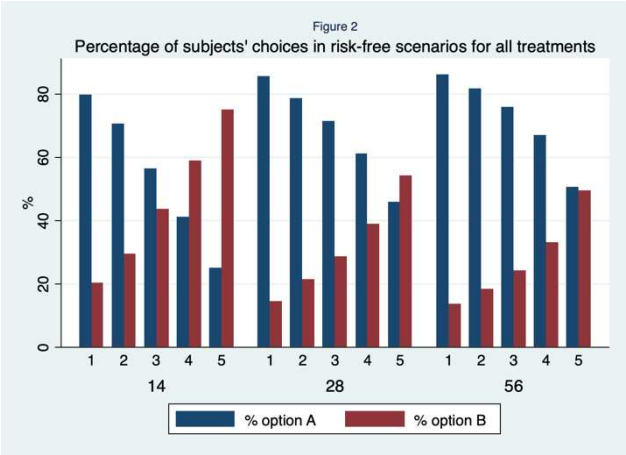
Table 2: Frequency of choices in risk-free scenarios (option A or B)

Treatment (time delay)	B value	Subjects choosing option A	Subjects choosing option B
14	22€	473 (79,76%)	120 (20,24%)
	24€	418 (70,49%)	175 (29,51%)
	26€	334 (56,32%)	259 (43,68%)
	28€	244 (41,15%)	349 (58,85%)
	30€	149 (25,13%)	444 (74,87%)
28	22€	224 (85,50%)	38 (14,50%)
	24€	206 (78,63%)	56 (21,37%)
	26€	187 (71,37%)	75 (28,63%)
	28€	160 (61,07%)	102 (38,93%)
	30€	120 (45,80%)	142 (54,20%)
56	22€	351 (86,24%)	56 (13,76%)

	24€	332 (81,57%)	75 (18,43%)
	26€	309 (75,92%)	98 (24,08%)
	28€	272 (66,83%)	135 (33,17%)
	30€	206 (50,61%)	201 (49,39%)

Sample size per treatment is: 593 in n=14; 262 in n=28; 407 in n=56.

In the case of certain scenarios, we show that there is a negative relation between the percentage of subject choosing option B and time delay. This result is visible in figure 2, in which is clear that the percentage of subjects choosing Option B is smaller the longer the temporal delay between two options.



In table 3 we report the results of a random effects probit estimation. Results show that the effect of the Average Daily Interest Rate (ADIR) is negative and significant, implying that the likelihood of choosing option A decreases when the ADIR increases.[5] Variables ADIR*28 and ADIR*56 are both positive and statistically significant, showing that the probability of choosing A increases with a time delay increase. The coefficient 28 Day Extension is positive but not significant, while the coefficient 56 Day Extension is positive and significant. This means that the longer the temporal extension, the fewer the share of subjects choosing the Option B. Finally, we can observe that demographic variables' coefficients are not statistically significant and, differently from the original study's estimates, the status of smoker is not statistically significant.

[5] Specifically: $value\ B\ at\ switch = E(option\ A)(1 + (it))$, where *i* is the Average Daily Interest Rate (ADIR).

Table 3: Random effects probit estimation of probability of choosing option A in risk-free scenarios

Explanatory Variable	**Coefficient**	**Robust Standard error**
Average daily interest rate (ADIR)	-1.910***	0.153
ADIR*28day extension	0.418*	0.187
ADIR*56day extension	0.438*	0 .176
28 day extension	0.711	0 .551
56-day extension	1.126*	0 .529
Gender	-0.0636	0 .254
Smoker	0.0350	0 .287
Constant	4.569***	0.428

** p<0.05, ** p<0.01, *** p<0.001*

We now present the results for the *risky scenarios*. In periods 6 through 25, subjects have to choose between two options in which at least one is risky. We analyzed how the introduction of risk affects subjects in their choices conducting a random effects probit regression of the choice of option A. As shown in table 4**,** in this regression we add a new variable in order to grasp some characteristics of the risky option. For the coefficients ADIR, ADIR*28 Day Extension, and ADIR*56 Day Extension we have the same results achieved in the previous regression. On the other hand, the coefficient 28 Day Extension and 56 Day Extension are both statistically significant. Consequently, the longer the temporal extension, the less likely participant are to choose option B. The coefficients of Risk in option A, Risk in option B, and Both options risky are negative and significant. This means that when the options become risky the probability of choosing A decreases. Finally, to explain the level of risk, we added a measure of the lotteries volatility: option A Standard Deviation and Option B Standard Deviation, respectively. The higher standard deviation value, the higher the risk in the lottery. In our results, the coefficients are negative and significant. This indicates that higher levels of risk are associated with lower probability of choosing earlier Option A, regardless of the risk is presented in Option A or Option B. Also in this estimate, the coefficients of demographic variables are statistically negligible.

Table 4: Random effects probit estimation of probability of choosing option A (full data set)

Explanatory Variable	**Coefficient**	**Robust Standard error**
Average daily interest rate (ADIR)	-0.722***	0.0213
ADIR*28 day extension	0.126***	0.036
ADIR*56 day extension	0.0713*	0.032
Risk in Option A	-1.129***	0.0478
Risk in Option B	-0.402***	0.0399
Both options risky	-1.066***	0.0488
Option A standard deviation	-0.0367***	0.0046
Option B standard deviation	-0.0425***	0.0052
28-day extension	0.352***	0.103
56-day extension	0.548***	0.089
Gender	0.0392	0 .0742
Smoker	-0.0358	0.0803
Constant	1.833***	.0852

** p<0.05, ** p<0.01, *** p<0.001*

To study the interaction between risk and length of the temporal delay, we used random effects probit estimation adding interactions between Risk in Option A, Risk in Option B, and Both Options Risky variables with 28 Day Extension and 56 Day Extension. The coefficients Risk in Option A*56 Day Extension and Risk in Option B*56 Day Extension are negative and significant (see table 5). This means that when only Option A is risky, and the temporal length delay is 56 days, the probability of choosing the Option A decreases. Although, when only Option B is risky and the temporal length delay is 56 days, the probability of choosing the Option A decreases.

Table 5: Random effects probit estimation of probability of choosing option A with risk and time interactions (full dataset)

Explanatory Variable	**Coefficient**	**Robust Standard error**
Average daily interest rate (ADIR)	-0.708***	0 .022
ADIR*28 day extension	0.132**	0 .041
ADIR*56 day extension	0.0152	0.037
Risk in Option A	-1.064***	0 .063
Risk in Option A*28day extension	0.00647	0 .118
Risk in Option A*56day extension	-0.232*	0 .105
Risk in Option B	-0.321***	0. .053
Risk in Option B*28day extension	0.0105	0.105
Risk in Option B*56day extension	-0.294**	0.091
Both options risky	-1.024***	0 .066
Both options risky*28day extension	0.0284	0 .12
Both options risky*56day extension	-0.174	0 .109
Option A standard deviation	-0.0368***	0 .004
Option B standard deviation	-0.0425***	0 .005
28 day extension	0.331*	0 .152
56 day extension	0.819***	0 .141
Gender	0.0389	0.074
Smoker	-0.0359	0 .0803
Constant	1.763***	0.093

** p<0.05, ** p<0.01, *** p<0.001*

4. Conclusion

The main aim of this work has been to investigate how intertemporal decision making is influenced by risk and uncertainty, by replicating the experimental design proposed by Anderson and Stafford (2009) through an online experiment. Comparing our results with the authors' ones, we can make some concluding remarks. We showed that in the non-risk scenarios the percentage of subjects choosing later Option B increases as the value option B increases. Furthermore, the percentage of subjects choosing Option B is smaller the longer the temporal delay between the two options. As in the original experiment proposed by Anderson and Stafford, the average daily interest rate is negatively and significantly related with the probability of choosing option A. Moreover, we observe that the variable *ADIR*28 Day Extension* is positive and statistically significant, while it turned out to be negative and statistically significant in the original study. Differently from the original study's evidence, in our experiment the effect of ADIR is consistent because both *ADIR*28 Day Extension* and *ADIR*56 Day Extension* coefficients are both positive and statistically significant. While in the replicated paper the authors found out that the variable *28 Day Extension* is positive and statistically significant, we found that the respective coefficient is positive but not statistically significant. Anyway, the *56 Day Extension* turned out to be positive and statistically significant, meaning that the longer the temporal extension, the less subjects choice Option B. We then analysed the effects of risk introduction on subjects' decision of choosing Option A, using data of all the treatments. The results for ADIR, ADIR*28 Day Extension and ADIR*56 Day Extension are consistent with the original study, as well as the positive and statistically significant coefficients of *28 Day Extension* and *56 Day Extension.* Concerning *Risk in Option A, Risk in Option B* and *Both options risky* coefficients, the original study found them to be positive and statistically significant, arguing that the presence of the risk makes subjects less patient. Otherwise, we obtained that these coefficients are negative and statistically significant. Anderson and Stafford also obtained that *Option A Standard Deviation* and *Option B Standard Deviation* are positive and statistically significant, concluding that higher levels of risk are associated with a higher probability of choosing the earlier option. On the contrary, our results show that both options' standard deviation coefficients are negative and statistically significant, implying that higher levels of risk are associated with a lower probability to choose earlier option, regardless of which option is risky. To conclude, we also aimed to understand whether there are interactions between risk and the length of the temporal delay. Although the original study found that none of the interaction coefficients was significant, we obtained that *Risk in Option A*56 Day Extension* and *Risk in option B*56 Day Extension* coefficients are negative and statistically significant, implying that there exist interactions between risk and the length temporal delay. Specifically, when the option A is risky, the higher the length temporal delay the less subjects choose Option A, while when the option B is risky, the higher length temporal delay the less subjects choose Option A. Thus, the interaction between risk and uncertainty seems to be not negligible in explaining the individual intertemporal decision making process.

Appendix

Questionnaire and instructions:

Choose one of the two options given. In each of them there are two different days of payment. One of all scenarios will be selected at random by drawing. For instance, if you chose Option A for the scenarios selected by drawing, you will receive the equivalent award.
Remember: only one of 25 scenarios will be selected.

Scenario 1: please choose between the following options:
 Option A: receive 20 euros in 14 days
 Option B: receive 22 euros in 28 days

Scenario 2: please choose between the following options:
 Option A: receive 20 euros in 14 days
 Option B: receive 24 euros in 28 days

Scenario 3: please choose between the following options:
 Option A: receive 20 euros in 14 days
 Option B: receive 26 euros in 28 days

Scenario 4: please choose between the following options:
 Option A: receive 20 euros in 14 days
 Option B: receive 28 euros in 28 days

Scenario 5: please choose between the following options:
 Option A: receive 20 euros in 14 days
 Option B: receive 30 euros in 28 days

Scenario 6: please choose between the following options:
 Option A: receive 20 euros in 14 days
 Option B: receive in 28 days, 20 euros if a red ball is drawn (50 out of 100) or 24 euros if a navy ball is drawn (50 out of 100)

Scenario 7: please choose between the following options:
 Option A: receive 20 euros in 14 days
 Option B: receive in 28 days, 16 euros if a red ball is drawn (50 out of 100) or 28 euros if a

yellow ball is drawn (50 out of 100).

Scenario 8: please choose between the following options:
 Option A: receive 20 euros in 14 days
 Option B: receive in 28 days, 22 euros if a purple ball is drawn (50 out of 100) or 26 euros if a black ball is drawn (50 out of 100).

Scenario 9: please choose between the following options:
 Option A: receive 20 euros in 14 days
 Option B: receive in 28 days, 24 euros if a navy ball is drawn (50 out of 100) or 28 euros if a yellow ball is drawn (50 out of 100).

Scenario 10: please choose between the following options:
 Option A: receive 20 euros in 14 days
 Option B: receive in 28 days, 20 euros if a red ball is drawn (75 out of 100) or 28 euros if a yellow ball is drawn (25 out of 100).

Scenario 11: please choose between the following options:
 Option A: receive 20 euros in 14 days
 Option B: receive in 28 days, 20 euros if a red ball is drawn (75 out of 100) or 36 euros if a white ball is drawn (25 out of 100).

Scenario 12: please choose between the following options:
 Option A: receive 20 euros in 14 days
 Option B: receive in 28 days, 16 euros if a pink ball is drawn (25 out of 100), 20 euros if a red ball is drawn (25 out of 100) or 26 if a black ball is drawn (50 out of 100).

Scenario 13: please choose between the following options:
 Option A: receive 20 euros in 14 days
 Option B: receive in 28 days, 16 euros if a pink ball is drawn (25 out of 100), 28 euros if a yellow ball is drawn (25 out of 100) or 36 if a white ball is drawn (50 out of 100).

Scenario 14: please choose between the following options:
 Option A: receive in 14 days, 18 euros if a gold ball is drawn (50 out of 100), 22 euros if a purple ball is drawn (50 out of 100)
 Option B: receive 22 euros in 28 days.

Scenario 15: please choose between the following options:
 Option A: receive in 14 days, 18 euros if a gold ball is drawn (50 out of 100), 22 euros if a purple ball is drawn (50 out of 100)
 Option B: receive 24 euros in 28 days.

Scenario 16: please choose between the following options:
 Option A: receive in 14 days, 18 euros if a gold ball is drawn (50 out of 100), 22 euros if a purple ball is drawn (50 out of 100)
 Option B: receive 26 euros in 28 days.

Scenario 17: please choose between the following options:
 Option A: receive in 14 days, 16 euros if a pink ball is drawn (75 out of 100), 32 euros if an orange ball is drawn (25 out of 100)
 Option B: receive 24 euros in 28 days.

Scenario 18: please choose between the following options:
 Option A: receive in 14 days, 12 euros if a clear ball is drawn (50 out of 100), 24 euros if a navy ball is drawn (25 out of 100) or 32 euros if an orange ball is drawn (25 out of 100)
 Option B: receive 24 euros in 28 days.

Scenario 19: please choose between the following options:
 Option A: receive in 14 days, 12 euros if a clear ball is drawn (25 out of 100), 20 euros if a red ball is drawn (25 out of 100) or 24 euros if a yellow ball is drawn (50 out of 100)
 Option B: receive 22 euros in 28 days.

Scenario 20: please choose between the following options:
 Option A: receive in 14 days, 18 euros if a gold ball is drawn (50 out of 100), 22 if a purple ball is drawn (50 out of 100)
 Option B: receive in 28 days, 20 euros if a red ball is drawn (50 out of 100), 24 euros if a navy ball is drawn (50 out of 100).

Scenario 21: please choose between the following options:
 Option A: receive in 14 days, 18 euros if a gold ball is drawn (50 out of 100), 22 euros if a purple ball is drawn (50 out of 100)
 Option B: receive in 28 days, 22 euros if a purple ball is drawn (50 out of 100), 26 euros if a black ball is drawn (50 out of 100).

Scenario 22: please choose between the following options:
 Option A: receive in 14 days, 18 euros if a gold ball is drawn (50 out of 100), 22 euros if a purple ball is drawn (50 out of 100)
 Option B: receive in 28 days, 20 euros if a red ball is drawn (75 out of 100), 36 euros if a black ball is drawn (25 out of 100).

Scenario 23: please choose between the following options:
 Option A: receive in 14 days, 16 euros if a red ball is drawn (75 out of 100), 32 euros if a orange ball is drawn (25 out of 100)
 Option B: receive in 28 days, 20 euros if a red ball is drawn (50 out of 100), 24 euros if a navy ball is drawn (50 out of 100).

Scenario 24: please choose between the following options:
 Option A: receive in 14 days, 12 euros if a clear ball is drawn (25 out of 100), 20 euros if a red ball is drawn (25 out of 100) or 24 euros if a yellow ball I drawn (50 out of 100)
 Option B: receive in 28 days, 16 euros if a pink ball is drawn (25 out of 100), 20 euros if a red ball is drawn (25 out of 100) or 26 euros if a black ball is drawn (50 out of 100)

Scenario 25: please choose between the following options:
 Option A: receive in 14 days, 12 euros if a clear ball is drawn (50 out of 100), 24 euros if a navy ball is drawn (25 out of 100) or 32 euros if an orange ball I drawn (25 out of 100)
 Option B: receive in 28 days, 16 euros if a pink ball is drawn (50 out of 100), 28 euros if a yellow ball is drawn (25 out of 100) or 36 euros if a white ball is drawn (25 out of 100)

Are you:
 male
 female

Age:
18-24
25-34
35-44
45-54
55-64
65+

Do you smoke? If you smoke, indicate the weekly frequency (e.g. If you smoke two packages a

week, you should write “2”. If you do not smoke, you should write “0”)

_____

Occupation:

 Self-employed

 Employed

 Housewife

 Unemployed

 Student

 Other

Inhabitants in the town of residence:

 Less of 5000

 By 5.000 to 19.999

 By 20.000 to 99.999

 By 100.000 to 1.000.000

 Over 1.000.000

What university did you go to/do you go to?

_____

What faculty did you go to/do you go to?

_____

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