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Myopic Loss Aversion under Ambiguity and Gender Effects*

Iñigo Iturbe-Ormaetxe, Giovanni Ponti and Josefa Tomás**

Abstract

Experimental evidence suggests that the frequency with which individuals get feedback information on their investments has an effect on risk-taking behavior. In particular, when they are given information sufficiently often, they take fewer risks compared with a situation in which they are informed less frequently. In this paper we find that this result still holds when subjects do not know the probabilities of the lotteries they are betting upon. We also detect significant gender effects, in that the frequency with which information is disclosed mostly affects men's betting behavior, rather than women's, and that men are much more risk-seeking after experiencing a loss.

Keywords: Myopic loss aversion, evaluation periods, ambiguity, gender effects.

JEL classification numbers: C91, D81, D14.

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1 Introduction

The so called *equity premium* is the difference between the return on stocks and the return on risk-free assets. Mehra and Prescott (1985) claim that this difference is too large to be explained by standard economic models, and coin the term "equity premium puzzle" to refer to this anomaly. They show that, to rationalize this phenomenon, individuals should hold a degree of risk aversion implausibly high. Benartzi and Thaler (1995) suggest that *Myopic Loss Aversion* (MLA) may help to solve this puzzle. MLA is described by two features, *i*) loss aversion and *ii*) mental accounting. Loss aversion is a cornerstone of Prospect Theory (Kahneman and Tversky, 1979) and refers to the tendency of individuals to weigh losses more heavily than gains. Mental accounting refers to the process individuals use to code and evaluate economic outcomes. In this respect, one relevant aspect is the frequency with which individuals evaluate the performance of their investments. Benartzi and Thaler (1995) find that loss averse individuals are more willing to take risks if they evaluate the results of their investments less frequently.

Several authors have designed experiments to test the empirical content of MLA in the lab. Thaler *et al.* (1997) design a portfolio choice experiment and find evidence that subjects are loss averse and that risk-taking behavior increases when information is given less frequently. They refer to this process as a way of "reducing myopia". Of most interest to us is the paper by Gneezy and Potters (1997, GP97 hereafter), who set up an experiment in which subjects face a sequence of nine i.i.d. lotteries. Each one of these lotteries gives a probability of 1/3 of winning 2.5 times the amount bet, and a probability of 2/3 of losing it. In one treatment ("high frequency", HF) subjects play the nine rounds one by one. At the beginning of each round they have to choose how much to bet. Then, before proceeding to the next round, they are informed about the realization of the lottery. In the other treatment ("low frequency", LF) subjects play rounds *in blocks of three*. That is, they must bet the same amount for the three lotteries in each block. These decisions are taken at the beginning of rounds 1, 4, and 7. Subjects are informed of the realization of lotteries at the end of rounds 3, 6, and 9. This design feature has an important impact on risk-taking behavior: consistently with MLA, subjects bet significantly more in the LF treatment. Other scholars have designed similar experiments to GP97, finding consistent evidence: people invest more when their myopia is corrected.[1]

A common feature of all this literature is that investment decisions are taken *under risk*, since subjects know the probabilities of the lotteries they are betting upon. This is only a first approximation of most real-life situations, where it is almost impossible to know precisely the probabilities associated with future returns when buying stocks, or choosing a job. In this respect, our main goal is to check whether GP97's findings *are*

[1] See Haigh and List (2005), Bellemare et al. (2005) and Langer and Weber (2005). Kliger and Levit (2009) find strong support for MLA using data from the stock market in Israel.

robust to ambiguity, i.e., if they carry over to situations in which subjects are unaware of the winning probability. To this aim, we borrow the basic GP97 layout, replicate their two treatments, and add two additional treatments (one with HF, another with LF) in which subjects *are not informed* about the winning probability. In this latter condition, consistently with Ellsberg's (1961) well known "paradox", we expect subjects to bet less than in the risky treatments, thus providing some evidence of ambiguity aversion, although it has been never documented whether MLA should be stronger under ambiguity.

In this respect, our experimental evidence shows that GP97's findings *are reinforced by the presence of ambiguity*, in that the increase in risk-taking from the HF to the LF treatment is even higher, as the average bet increases a 38.9% from HF to LF under risk, and a 57.1% under ambiguity.[2] On the other hand, we also detect significant ambiguity aversion (in that subjects, on average, bet less than in the corresponding risky conditions), although the ambiguity dimension seems less prominent than the frequency dimension.

We also look at gender differences in our data. In this respect, we find that women bet, on average, less than men. While men bet, on average, 53.5% of the endowment, women bet only 46.6%. Interestingly enough, this difference only takes place in the LF treatments: 65.6% and 53.3% for men and women, respectively. In the HF treatments average bets are practically identical: 40.3% *vs.* 40.4%. Another interesting finding is that the increase in risk-taking from HF to LF treatments that we have observed is mainly due to changes in men's behavior. The increase from HF to LF is 62.8% for men, and 31.9% for women, respectively. That is, men seem to be extremely sensitive to the frequency dimension, while women change behavior much less. Finally, we also find that, in our sample, men are much more affected by a previous loss than women. In general, we find that subjects are more risk-seeking after experiencing a loss, increasing their bets a 21.5% on average. While women on average only increase their bets an 8%, men increase their bets a 39%.

With the premise of these findings, we frame subjects' decisions within the realm of a simple (piecewise linear) MLA utility maximization problem, where, in the ambiguous treatments, we also elicit our participants' subjective winning probability. As our structural estimates indicate, *i*) in the LF treatments *subjects' myopia is only partially corrected*, in that the estimated loss aversion coefficient increases significantly (with, apparently, no gender difference) compared to that estimated in the HF treatments and that *ii*) gender differences occur at the level of elicited beliefs, rather than structural differences in the value function. Women (men) over (under) estimate the winning probability in the LF treatments, compared to the control HF condition, and we cannot reject

[2]Contrary to what has been suggested by Blavatskyy and Pogrebna (2009, 2010), we find that the difference between LF and HF treatments is not driven by subjects with "extreme" behavior, i.e., who systematically bet either 0% or a 100% of their endowments. Differences remain significant even when we exclude such individuals from our sample.

the null that the elicited probability is not different than the "objective" one. These offsetting effects make it possible that the frequency effect we detect in the ambiguous treatments is much stronger for men than for women.

The remainder of the paper is arranged as follows. In Section 2 we describe our experiment. In Section 3 we provide some descriptive statistics, while Section 4 explores gender differences in detail. In Section 5 we present three sets of estimates of the parameters of our structural behavioral model of MLA, while Section 6 concludes, followed by an Appendix containing additional statistical evidence and the experimental instructions.

2 Experimental design

2.1 Sessions

We ran 4 sessions of 24 subjects per session, for a total of 96 individuals, 46 men and 50 women. All subjects were recruited from the undergraduate population of the Bachelor Degree in Business Administration of the University of Alicante. Experiments were carried out with paper and pencil in classrooms which seat 100 individuals, so that the 24 participants in each session could be easily separated from one another and decide in isolation.

The experiment consists of a sequence of nine independent lotteries. In each round, subjects are endowed with 100 eurocents. They have to decide the amount $x \in [0, 100]$ of their endowment they want to bet in a lottery which returns two and a half times the amount invested with a probability of 1/3 while, with a probability of 2/3, all the invested money is lost. Subjects were privately paid off in cash their cumulative earnings right after the end of the experiment. Average earnings were 9.36 euro for an experiment that, on average, lasted 40 minutes.

2.2 Treatments

We borrow the basic design layout from GP97. Our two baseline treatments, T1 and T2, replicate GP97's HF and LF conditions under risk. As we mentioned in the introduction, in the HF condition subjects decide over their investment in each and every round, while in the LF treatment they only decide once every three rounds. Our alternative treatments, T3 and T4, implement under ambiguity HF and LF conditions, respectively. The lottery subjects play is the same as in treatments T1 and T2, but no information is disclosed about the winning probability, except that such probability stays constant across rounds.

We refer to T1 and T2 as *Risky* (R) treatments and to treatments T3 and T4 as *Ambiguous* (AMB) treatments, as sketched in Table 1.

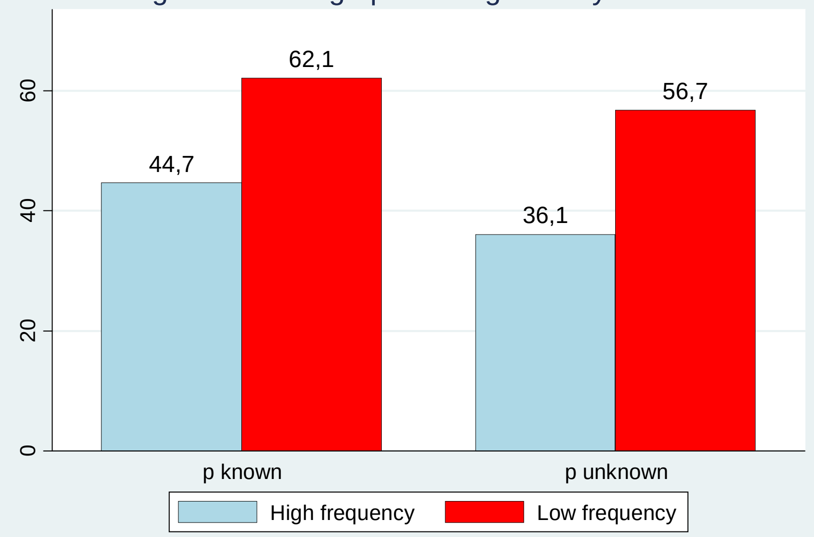
Table 1: The four treatments

Treatments	Risk	Ambiguity
High Frequency	T1 (HF-R)	T3 (HF-AMB)
Low Frequency	T2 (LF-R)	T4 (LF-AMB)

3 Results

Figure 1 tracks average bets in the four treatments. As Figure 1 shows, our results are in line with the literature we discussed in the introduction: *subjects bet more in the LF treatments.* As Figure 1 shows, *this difference in behavior is even higher under ambiguity* (treatments T3 and T4). Moreover, our aggregate data also show *some evidence of ambiguity aversion* in that, keeping frequency fixed, subjects bet less in the ambiguous treatments. In the HF case the average bet falls a 19.2% while in the LF case it falls a 8.7%.

Figure 1: Average percentage bet by treatment



In what follows we shall look at our data in more detail, exploiting the two dimensions of our experimental design: HF *vs.* LF (Section 3.1), and risk *vs.* ambiguity (Section 3.2).

3.1 HF vs. LF

We begin by presenting the results of treatments T1 and T2. Table 2a replicates exactly Table 1 in GP97 using our data.

Table 2a: Average bets, T1 and T2*

	T1	T2	Mann-Whitney
Rounds 1-3	42.5 (22.8)	51.9 (19.0)	-1.71 [.088]
Rounds 4-6	42.4 (25.4)	62.4 (21.2)	-3.12 [.002]
Rounds 7-9	49.0 (27.0)	72.2 (26.4)	-2.93 [.003]
Rounds 1-9	44.7 (24.9)	62.1 (23.6)	-2.84 [.004]

*Standard deviations in parenthesis

As Table 2a shows, our results are very much in line with those of GP97 and Haigh and List (2005). We find that average bets are significantly higher in T2. Differences are always statistically significant, whether we consider each block of three rounds alone, or all rounds altogether.[3]

Blavatskyy and Pogrebna (2009, 2010) claim that this difference in behavior can be driven by the "extreme" behavior of subjects who systematically choose a corner solution, either 0 or 100. For this reason, they propose to partition the experimental subjects into three groups: (i) those who consistently invest 100% of their endowment at least 5 rounds out of 9; (ii) those who consistently invest 0% of their endowment at least 5 rounds out of 9 and, (iii) the remainder. They compare behavior across treatments using the original data of GP97, Haigh and List (2005), and Langer and Weber (2005), but only for individuals in Group (iii). They find that differences are no longer statistically significant, except for the case of professional traders in Haigh and List (2005). To check whether this also happens with our data, we drop subjects in groups (i) and (ii) and calculate average bet by treatment. Results are reported in Table 2b, which is obtained by excluding a total of four subjects out of 48 (three in Treatment 1 and one in Treatment 2).

Table 2b: Average bets, T1 and T2, group (iii) only*

	T1	T2	Mann-Whitney
Rounds 1-3	35.9 (14.8)	50.6 (18.4)	-2.55 [.011]
Rounds 4-6	34.2 (13.2)	60.7 (20.1)	-4.09 [.000]
Rounds 7-9	41.7 (19.8)	70.9 (26.3)	-3.69 [.000]
Rounds 1-9	37.3 (16.2)	60.8 (23.1)	-3.83 [.000]

*Standard deviations in parenthesis

As Table 2b shows, when we exclude extreme behavior from the sample, differences get even higher.

[3] In Table 2a (and all that follows) statistical significance is measured by (2-tailed) non-parametric Mann-Whitney statistics.

We now move to our "ambiguous" treatments, T3 and T4, checking whether the frequency effect we detected under risk still persists under ambiguity. Results are reported in Table 3, where we again observe that individuals bet a significantly higher amount in the LF treatment. In fact, differences between T3 and T4 are slightly bigger than differences between T1 and T2. As above, we also drop individuals with an extreme behavior (we dropped five individuals, all of them in T3). Even in this case we find that, on average, individuals still bet significantly more in the LF treatment, although the difference is slightly reduced.[4]

Table 3: Average bets, T3 and T4*

	T3	T4	Mann-Whitney
Rounds 1-3	31.6 (20.3)	49.7 (20.2)	-3.42 [.001]
Rounds 4-6	33.4 (21.2)	52.9 (17.7)	-3.16 [.002]
Rounds 7-9	43.1 (29.7)	67.7 (19.3)	-2.98 [.003]
Rounds 1-9	36.1 (24.3)	56.7 (20.4)	-3.83 [.000]

*Standard deviations in parenthesis

3.2 Risk *vs.* ambiguity

Table 4 compares the HF treatments T1 and T3.

Table 4: Average percentage bet, T1 and T3*

	T1	T3	Mann-Whitney
Rounds 1-3	42.5 (22.8)	31.6 (20.3)	1.82 [.069]
Rounds 4-6	42.4 (25.4)	33.4 (21.2)	1.17 [.243]
Rounds 7-9	49.0 (27.0)	43.1 (29.7)	.60 [.549]
Rounds 1-9	44.7 (24.9)	36.1 (24.3)	.99 [.322]

*Standard deviations in parenthesis

As Table 4 shows, subjects' behavior exhibits some ambiguity aversion, in that the average bet is lower in T3. However, this effect seems lower than the frequency effect we discussed in Section 3.1, in that difference in betting is significant only when we consider the first three rounds. In Table 5 we repeat the same exercise using data from T2 and T4. Again, we find that individuals bet more in T2, although differences are never significant.

[4] Descriptive statistics are not reported here, but are available upon request.

Table 5: Average percentage bet, T2 and T4*

	T2	T4	Mann-Whitney
Rounds 1-3	51.9 (19.0)	49.7 (20.2)	.39 [.699]
Rounds 4-6	62.4 (21.2)	52.9 (17.7)	1.31 [.191]
Rounds 7-9	72.2 (26.4)	67.7 (19.3)	.84 [.400]
Rounds 1-9	62.1 (23.6)	56.7 (20.4)	1.21 [.227]

*Standard deviations in parenthesis

4 Gender effects

Previous studies have pointed out that women are more risk averse than men (see, for instance, Bertrand, 2011), although evidence is mixed and often depends on the experimental setting under scrutiny (Croson and Gneezy, 2007). Table 6 compares average bets of women and men in our four treatments, T1 to T4.

Table 6: Gender differences by treatments

	Men	Women	Mann-Whitney
T1	44.8 (25.3)	44.6 (22.4)	.12 [.905]
	N=9	N=15	
T2	71.2 (12.0)	54.5 (20.8)	1.89 [.058]
	N=11	N=13	
T3	37.2 (15.6)	34.7 (21.0)	.20 [.839]
	N=13	N=11	
T4	60.8 (15.0)	52.0 (14.9)	1.43 [.154]
	N=13	N=11	
All	53.5 (21.3)	46.6 (21.0)	1.69 [.091]
	N=46	N=50	

*Standard deviations in parenthesis; N: number of individuals.

As Table 6 shows, men invest more than women. When we consider the four treatments altogether this difference is statistically significant at the 10% level. However, gender differences seem to be highly dependent on treatment conditions. Specifically, we find a significant difference only in T2 (low frequency with known probability).

As we discussed in Section 3.2, in our data, MLA seems more pronounced than ambiguity aversion at the aggregate level. With this premise, Table 7 measures treatment effects disaggregated by gender.

Table 7: Treatment differences by gender*

	T1	T2	Mann-Whitney	T3	T4	Mann-Whitney
Men	44.8 (9)	71.2 (11)	-2.70 [.007]	37.2 (13)	60.8 (13)	-3.08 [.002]
Women	44.6 (15)	54.5 (13)	-1.27 [.205]	34.7 (11)	52.0 (11)	-2.37 [.018]
All	44.7 (24)	62.1 (24)	-2.84 [.004]	36.1 (24)	56.7 (24)	-3.83 [.000]

	T1	T3	Mann-Whitney	T2	T4	Mann-Whitney
Men	44.8 (9)	37.2 (13)	.63 [.526]	71.2 (11)	60.8 (13)	1.71 [.086]
Women	44.6 (15)	34.7 (11)	.75 [.451]	54.5 (13)	52.0 (11)	.14 [.885]
All	44.7 (24)	36.1 (24)	.99 [.322]	62.1 (24)	56.7 (24)	1.21 [.227]

*Number of individuals in parenthesis.

Table 7 discloses an interesting pattern related with gender: the difference in average bets between T1 and T2 is mainly driven by men. In fact, although women bet more in T2 than in T1 (54.5 vs. 44.6), this difference is not statistically significant. Then, we see that the "frequency effect" we found above is mainly driven by a large difference in average betting by men from T2 to T1 (71.2 vs. 44.8). Thaler *et al* (1997) interpret the change in framework from T1 to T2 as a "correction of myopia." This is done in two ways: (i) by committing individuals for multiple periods, and (ii) by giving them information relatively infrequently. With this interpretation in mind, our results seem to imply that, under risky conditions women's risk-taking behavior is less sensible to a correction of myopia. Regarding T3 and T4, we find that both genders bet significantly more in the LF treatment, although the effect is, again, stronger for men.

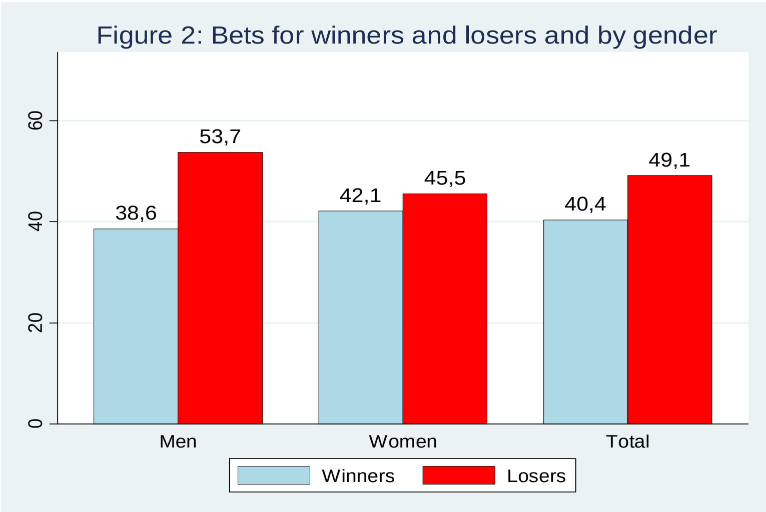
We now move to another behavioral pattern we find in our data which has a strong gender component. Precisely, we check whether subjects modify their behavior after experiencing a loss and if such change displays gender differences. Thaler and Johnson (1990) consider this issue but they do not find a clear-cut prediction about how previous losses may affect behavior.

Our first task is to define *who is a loser* in our experimental context. For T1 and T3 this is relatively straightforward: in a given round, t, we say that an individual is a loser if she lost money in round $t-1$. As for T2 and T4, defining who is a loser is not as straightforward, since in the LF treatments subjects only take three decisions (in rounds 1, 4, and 7), so we can only take into account the second and third decisions. In this respect, there are (at least) two alternative definitions of a loser.

1. Subject i is a loser in period 4 (period 7) if she lost money in at least 2 out of 3 periods in periods 1-3 (periods 4-6).

2. Subject i is a loser in period 4 (period 7) if she lost money in periods 1-3 (periods 4-6) on average.[5]

In Figure 2 we display average bets disaggregated for gender and "losers." We use data of our four treatments using Definition 1.[6]



When we do not disaggregate by gender (right block), we find that individuals bet a 21.5% more on average after experiencing a loss. Interestingly, when we decompose by gender we find that almost all this change in behavior is driven by men, since women do not seem to be so much affected by previous losses. Women on average only increase their bets an 8%, while men increase their bets a 39%.

In Appendix A.2 we report some additional statistics over other interesting behavioral evidence, related with end-game effects, together with the estimated coefficients of a Tobit regression in which the amount bet by each subject is explained by period, treatment conditions, gender and our "loser" dummy.

Our main findings until here are:

1. Individuals bet more in LF treatments, independently of whether they know or do not know the probability of winning. This result is still true when we eliminate individuals with extreme behavior.

2. When the probability is known, most of the increase in bets when moving to a LF treatment is due to a change in behavior among men.

[5]Notice that, because of our experimental design, this requires having lost in the three previous periods.

[6]See the Appendix for the same table using Definition 2.

3. Women bet less on average than men, although this difference is statistically significant only in some specifications.

4. Men take more risks after a loss, while women do not seem to be very much affected by previous losses.

5. We find strong end-game effects, as average bets increase in the last decision round, both for HF and LF treatments.

5 Structural estimations

One of the standard models that have been used to explain the difference in behavior between HF and LF treatments is Myopic Loss Aversion (MLA). This theory rests on two concepts. The first one is *loss aversion* (Kahneman and Tversky (1979) and Tversky and Kahneman (1992)): individuals have a greater sensitivity to losses than to gains. The second one is *myopia*, that is, the tendency of individuals, when given the chance, to evaluate outcomes too frequently, failing to consider the "compound lottery" induced by the multi-period decision setting.

The simplest utility function that captures loss aversion assumes that the value function v is piece-wise linear:

$$v(x) = \begin{cases} x & x \geq 0 \\ \lambda x & x < 0, \end{cases} \tag{1}$$

where λ is the loss aversion coefficient.

As for myopia, we consider the HF decision problem as structurally different from its LF counterpart since, in the latter case, subjects should consider the compound lottery induced by three i.i.d. lotteries over the same investment, x. In the HF treatments, T1 and T3, subjects face the lottery $L_{HF}(x) = (2.5x, p; -x, 1-p)$, where $0 \leq x \leq 100$ and $p = \frac{1}{3}$ in our experiment. An individual who evaluates lotteries with a value function as in (1) faces the following maximization problem:

$$\max_x V(L_{HF}(x)) = (2.5p - \lambda(1-p))\, x, \tag{2}$$

with a maximum $x^* = 100$ ($x^* = 0$) if $\lambda < (>) \frac{5p}{2(1-p)}$(=1.25 when $p = \frac{1}{3}$).

In the LF treatments, T2 and T4, an individual who builds the compound lottery induced by the three i.i.d. draws, faces the following compound lottery:

$$L_{LF}(x) = \left(7.5x, p^3; 4x, 3p^2(1-p); 0.5x, 3p(1-p)^2; -3x, (1-p)^3\right), \tag{3}$$

which, in turn, yields the following maximization problem:

$$\max_x V\left(L_{LF}(x)\right) = \frac{3}{2}\left(-2\lambda(1-p)^3 + p(1+6p-2p^2)\right)x, \tag{4}$$

with a maximum $x^* = 100$ ($x^* = 0$) if $\lambda < (>) \frac{p(1+6p-2p^2)}{2(1-p)^3} (= 1.56$ when $p = \frac{1}{3})$.

Two simple considerations at this stage. First, this specific "all-or-nothing" feature of the optimal solution is simply a by-product of the (piecewise) linearity of the value function (1) which, in turn, implies that lotteries' expected payoffs $V(\cdot)$ are linear in x. Our implicit functions $\lambda_{HF}(p) = \frac{5p}{2(1-p)}$ and $\lambda_{LF}(p) = \frac{p(1+6p-2p^2)}{2(1-p)^3}$ define the two contours for which the slope of the expected payoff functions is zero (i.e., the only values of λ and p compatible with an interior optimal solution). Notice that *both* $\lambda_{HF}(\cdot)$ *and* $\lambda_{LF}(\cdot)$ *are increasing functions*: to preserve indifference, a change in loss aversion needs to be compensated with a change of the winning probability in the same direction.

Also notice that $\lambda_{HF}(p = 1/3) = 1.25 < 1.56 = \lambda_{LF}(p = 1/3)$, i.e., in the LF treatments the threshold level for λ compatible with payoff indifference *is higher*. This is what the literature refers as the reduction of myopia induced by loss aversion. Aggregating gains and losses in the compound lottery implies that the individual may lose money in only one out of four possible states, compared to one out of two in the HF treatment.

5.1 Statistical Model

Every individual i has to choose an amount to bet among m alternatives possibilities in every round t. Her utility when choosing the alternative j in round t is:

$$U_{ijt} = V_{ijt}(\beta) + \varepsilon_{ijt}, \tag{5}$$

for $j = 1, 2, .., m$, $t = 1, 2, .., T$, and $i = 1, 2, .., N$. Here β represents the unknown utility parameters. The terms V_{ijt} and ε_{ijt} denote deterministic and random components of i's utility, respectively. Depending on the structure of our theoretical model and the treatment, we shall propose three different expressions for the deterministic component V_{ijt} (see Section 5.2 below). According with our random utility model, individual i selects alternative j in round t with probability:

$$\begin{aligned} P_{ijt} &= \Pr[U_{ijt} \geq U_{ikt}, \text{ for all } k \neq j] = \\ &= \Pr[\varepsilon_{ikt} - \varepsilon_{ijt} \leq V_{ijt} - V_{ikt}, \text{ for all } k \neq j]. \end{aligned} \tag{6}$$

We assume that the errors ε_{ijt} are independent across choices and individuals and are distributed as type I extreme value:

$$\Pr[\varepsilon \leq z] = \exp(-\exp(-z)). \tag{7}$$

Under this distributional assumption, the probability of choosing alternative j follows the conditional multinomial logit model:

$$P_{ijt} = \frac{\exp(V_{ijt}(\beta))}{\exp(V_{i1t}(\beta)) + \exp(V_{i2t}(\beta)) + ... + \exp(V_{imt}(\beta))}. \tag{8}$$

Assuming that the individual chooses the alternative j^*, the probability of the observed sequence of choices of individual i is:

$$P_i(\beta) = \prod_{t=1}^{T} P_{ij^*t}(\beta), \tag{9}$$

and the log-likelihood function is:

$$L(\beta) = \sum_{i=1}^{N} \log P_i(\beta). \tag{10}$$

As for the ambiguity treatments T3 and T4, we follow Andersen *et al.* (2010) in eliciting i's subjective probability, p, by maximum likelihood, together with our (only) utility parameter, λ. For the risky treatments T1 and T2 it is assumed that $p = 1/3$.

5.2 Estimations

We present all our estimates in Table 9. We show the results of three alternative models. In Model 1 we report maximum likelihood estimates assuming homogeneous agents, i.e., estimating our parameters as constant across gender and treatments. In models 2 and 3 we allow for some heterogeneity. In Model 2 we report estimates for gender and treatments (constant). In Model 3 we interact our gender dummy with the two treatment conditions, LF and AMB (for ambiguity, T3 and T4).

Table 9: Estimates of parameters*

Parameters		Model 1	Model 2	Model 3
λ	constant	1.3170 (.0392)	1.2530 (.0097)	1.2576 (.0121)
		$[1.2401, 1.3938]$	$[1.2339, 1.2722]$	$[1.2339, 1.2814]$
	female		.0073 (.0100)	$-.0000$ (.0148)
			$[-.0122, .0269]$	$[-.0290, .0290]$
	AMB		.0091 (.0107)	$-.0042$ (.0124)
			$[-.0118, .0300]$	$[-.0285, .0201]$
	LF		.2905 (.0085)	.2780 (.0132)
			$[.2739, .3071]$	$[.2520, .3039]$
	AMB_female			.0005 (.0136)
				$[-.0182, .0352]$
	LF_female			.0171 (.0166)
				$[-.0155, .0497]$
p	constant	.3390 (.0071)	.3321 (.0034)	.3305 (.0035)
		$[.3249, .3530]$	$[.3254, .3387]$	$[.3236, .3374]$
	female		.0006 (.0028)	.0007 (.0043)
			$[-.0050, .0061]$	$[-.0078, .0093]$
	LF		.0370 (.1855)	$-.0456$(.0045)
			$[-.3265, .4005]$	$[-.054, -.036]$
	LF_female			.08414 (.006)
				$[.0721, .0961]$
	Log-likelihood	-2458.571	-1348.146	-1346.456
	Observations	576	576	576

*St. errors in parenthesis and 95% confidence intervals in brackets.

The estimated values we obtain for the parameter λ are always above one. This seems to express that our experimental individuals are indeed loss averse. In fact, in all cases the 95% confidence interval for the coefficient of loss aversion λ lies strictly above 1.

With respect to the estimates of the probability p, in most cases we cannot reject the null hypothesis that the subjective winning probability corresponds to its "true value" 1/3.

In Model 1 we assume that all subjects share the same values of the two parameters, λ and p. The estimated value of λ is 1.3170, and its 95% confidence interval is [1.2401, 1.3938]. As for p, the null hypothesis of no probability bias is confirmed by our structural estimation.

In Model 2 we estimate our parameters by conditioning by treatments (LF and AMB) and gender. Here we find evidence that the "frequency effect" predominates those related with ambiguity and gender. Surprisingly so, the estimated coefficient for LF is *positive*, thus indicating an increase of estimated loss aversion in the LF treatments. For males in the HF treatments we estimate $\widehat{\lambda}_{HF} = 1.2530$, and for the LF treatments we get $\widehat{\lambda}_{LF} = 1.5435$. How can we reconcile this with the fact that individuals raise their bets from HF to LF treatments? Recall that MLA predicts that only individuals with $\lambda \leq 1.25$ will bet in HF treatments, while in LF treatments the threshold is 1.56. Then, what is important is not the particular estimations we get $\widehat{\lambda}_{HF}$ and $\widehat{\lambda}_{LF}$, but how they are related with their corresponding thresholds. In the HF case, both the estimated coefficient of loss aversion and the threshold are lower than in the LF case. But in the LF case, since the estimated coefficient is more to the left of its corresponding threshold compared to the HF case, a larger fraction of individuals are willing to bet.

Finally, in Model 3 we interact gender with treatment conditions. Consistently with Fehr-Duda *et al.* (2006), we detect a clear gender effect at the level of subjective beliefs, rather than a shift in loss aversion. In the LF treatments men adjust subjective beliefs downward a 5% with respect to the "true value" 1/3, while women increase theirs an 8%. Together with the average increase in the estimated loss aversion parameter, this explains the strong gender component in the increase of average bets from T3 to T4. As we already discussed, our estimated parameters correspond roughly to the indifference thresholds (i.e., the only estimated values that allow for an optimal interior bet). A lower threshold for males implies a larger interval for subjective beliefs compatible with full betting, while for females the two effects seem to compensate each other, yielding betting behavior less sensitive to treatment conditions.

6 Conclusions

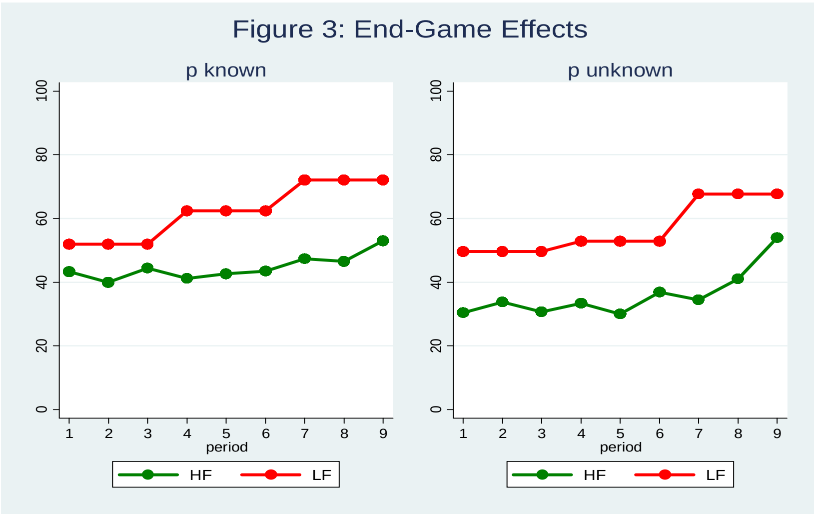
The main scope of this paper is to check the robustness of MLA under ambiguity, i.e., when individuals are uncertain about the winning probability. In this respect, our results confirm that forcing people to consider the compound lottery induced by the multi-period structure of the experiment has a significant impact on betting behavior, and that such impact is even stronger under conditions of ambiguity. We also find that betting behavior has a clear gender component, not much at the aggregate level but, rather, when we look at differences in behavior induced by treatment conditions. Males bet, on average, slightly more than females. More important, men's behavior seems much more sensitive to changes in the betting environment. The increase in average betting under LF conditions is much stronger for males, and so is the increase in average betting after experiencing a loss, no matter how a loss is defined.

Our structural estimation exercise seems to suggest that -consistently with previous literature- these gender differences are due to the structural changes in the process of subjective belief formation, rather than to structural changes in the value function (i.e., a change in loss aversion). This latter piece of evidence seems very promising in light of future research on the very active area of (experimental) gender economics.

Appendix A: Additional statistical evidence

A.1: End-game effects

Here we analyze whether there are end-game effects. These effects refer to whether individuals exhibit a different behavior in the last rounds of the experiment. In Gneezy and Potters (1997), Langer and Weber (2005), and Haigh and List (2005) individuals bet more in the last rounds. This may be due again to a "break-even" effect or simply to an income effect. Typically, accumulated wealth is higher in the last part of the experiment. We now try to isolate this effect. In Figure 3 we present average bets across the nine periods for our four treatments.[7]



In our four treatments we find that the average bet rises from period 1 to period 9, which could be due to an income effect. However, we find that most of this increase happens when individuals take their last decisions (period 9 in T1 and T3, period 7 in T2 and T4). This change in the last decision seems to be more a pure end-game effect rather than only an income effect. Finally, we find comparable end-game effects when individuals know and when they do not know the probability of winning the lottery. That is, we observe both in the left (known probability) and right panel (unknown probability) that the increase from period 8 to 9 in the HF treatment is similar to the increase from period 6 to 7 in the LF treatment.

A.2: Individual data

Here we want to identify the main factors affecting individual decisions about how much to bet. Our dependent variable is the amount that the individual decides to bet, and it takes values from 0 to 100. In treatments 1 and 3 each individual takes 9 decisions, while in treatments 2 and 4 they only decide three times. Therefore, the total number

[7]Figure 3 does not disaggregate data by gender since, in this case, gender differences are never significant.

of observations is $24 \times 2 \times 9 + 24 \times 2 \times 3 = 576$. Since our dependent variable is censored between 0 and 100, we will estimate a Tobit model. The list of regressors we propose to include is as follows:

- **LF:** This is a dummy variable that takes value 1 in treatments 2 and 4 (0 otherwise), that is, in the LF treatments.
- **AMB:** Another dummy variable that takes value 1 in treatments 3 and 4 (0 otherwise) in which the probability is unknown.
- **LF*AMB:** Takes value 1 only in Treatment 4. It measures the interaction between **LF** and **AMB**.[8]
- **gender:** Takes value 1 for women and 0 for men.
- **period:** We include a dummy variable for each period from period 2 to period 9. These variables capture time effects.
- **loser:** Takes value 1 when the individual experienced a loss in the previous round (treatments 1 and 3) or when she experienced a loss in at least 2 out of 3 rounds in the previous block (treatments 2 and 4). This corresponds to our Definition 1 in Section 4.
- **gender*loser**: This is an interaction between **gender** and **loser** and takes value 1 if the individual is a woman loser. Here we want to see if the effect of previous outcomes differs by gender.

To allow for arbitrary patterns of correlation within each individual's choices in all of our regressions, robust standard errors are clustered at the individual level. In Table 8 we show the marginal effects on the dependent variable from our Tobit model. We present the results corresponding to three alternative models

[8] Alternatively we could define a dummy variable for each one of the treatments 2, 3, and 4.

Table 8: Tobit regression marginal effects

Variables	Model 1	Model 2	Model 3
LF	8.76** (4.16)	10.27*** (4.36)	11.48*** (4.75)
AMB	-7.00** (3.54)	-7.06** (3.61)	-5.23 (3.56)
LF*AMB	3.22 (4.52)	3.17 (4.62)	1.30 (4.66)
gender	-2.09 (2.95)	-2.16 (3.01)	4.19 (3.51)
period 7		7.12*** (1.95)	2.83 (2.40)
period 8		6.18** (3.15)	3.36 (3.14)
period 9		12.53*** (3.56)	9.23*** (3.69)
loser			11.70*** (3.68)
gender*loser			-9.41** (4.06)
Observations	576	576	480

Standard errors in brackets; *, **, *** indicate significance levels of 90, 95 and 99%, respectively.

In Model 1 we only include four dummy covariates. In Model 2 we also include dummies for all periods from 2 to 9, although in the table we only report the marginal effects corresponding to the last three periods, since these are the only ones that are statistically significant. Finally in Model 3 we include two additional dummies. In Model 3 we lose 96 observations because when we introduce the regressor "loser" we have to eliminate each individual's first decision. This implies the elimination of $24 \times 4 = 96$ observations.

In all our three specifications we find that the coefficient of **LF** is strongly significant. In our third specification, on average, individuals increase their bets from T1 to T2 by a 11.48%. Our second dummy variable, **AMB**, has a negative effect on the bet. This variable captures the effect of going from T1 to T3. We find a significant effect only in models 1 and 2. For instance, in Model 2 we find that individuals reduce their bets from T1 to T3 a 7.06%, on average. These results seem to confirm our initial observation that the frequency dimension matters more than the ambiguity dimension. Our third dummy variable, **LF*AMB**, is an interaction between the two previous variables. Its coefficient is never significant. However, since the corresponding marginal effect is positive, this means that the effect of going from HF to LF is stronger when the probability is unknown compared to the case in which the probability is known. We also find that the negative effect of introducing ambiguity is stronger when frequency is high compared to the LF case.

In models 1 and 2 we find that women tend to bet less than men, although differences are not statistically significant. When we include period dummies (Model 2), we find that individuals bet more in the last three periods as seen in Figure 3. In particular, in the last period individuals bet around a 12.5% more compared to the first period. In Model 3 we only find a significant effect in period 9. This end-game effect can be due to different reasons. It could be due to a pure end-game effect, or to the fact that individuals have more money in the last stages of the game, or to a break-even effect as we commented in Section 4.[9]

In Model 3 we control for the effect of having experienced a loss in the previous round. What we find confirms what we saw above: the effect of having lost money in a previous round is completely different for men than for women. While men, on average, increase their bet in a 11.70% after experiencing a loss, the effect on women is much smaller. In particular, they increase their bet only a 2.29% (11.70-9.41). That is, the effect of experiencing a loss has an effect on the bet in the next round that is five times higher for men than for women.

[9] In another regression, not presented in the paper, we add to our regressors the accumulated profit but we obtain that its coefficient is never significant and its value is very close to zero.

Appendix B: Experimental instructions

This is the translation into English of the original instructions in Spanish.

Treatment 1 (T1, HF-R)

Welcome to this experiment in decision-making. The experiment will take about 30 minutes. Instructions are very simple and you can earn a sizable amount of money. The money that you earn will be paid in cash at the end of the experiment.

The experiment has nine rounds. In each round you will be endowed with 100 cents (€1). You will be asked to choose the portion x of this amount that you wish to invest in a risky option. This option is the same for the nine rounds.

The risky option: there is a 1/3 chance that the investment will be successful. If it is successful you will receive 2.5 times the amount you chose to bet. If the investment is unsuccessful (a chance of 2/3) you lose the amount you bet.

How do we determine if the investment is successful?

Each one of you has a record sheet with a letter A, B, or C at the top. In each round, one of you will take out a ball from a bag that contains three balls marked with the letters A, B, or C. If the letter chosen coincides with your letter you will win. Otherwise you will lose.

How can I calculate my earnings?

For each round, if you win you have to add your invested amount (x) multiplied by 2.5 to the initial endowment of 100 cents. If you lose, you have to deduct the invested amount (x) from the initial endowment.

At the end of the experiment you have to add up the amounts of the nine rounds and this is the total amount you will be paid in cash.

Treatment 2 (T2, LF-R)

Welcome to this experiment in decision-making. The experiment will take about 30 minutes. Instructions are very simple and you can earn a sizable amount of money. The money that you earn will be paid in cash at the end of the experiment.

The experiment has nine rounds divided in blocks of three rounds. In each round you will be endowed with 100 cents (€1). At the beginning of the first round you will be asked to choose the portion x of this amount that you wish to invest in the first, second and third round. In the fourth round you have to choose the amount you wish to invest in the fourth, fifth and sixth rounds. Lastly, in the seventh round, you have to choose the amount for the seventh, eight and ninth rounds.

The risky option: there is a 1/3 chance that the investment will be successful. If it is successful you will receive 2.5 times the amount you chose to bet. If the investment is unsuccessful (a chance of 2/3) you lose the amount you bet.

How do we determine if the investment is successful?

Each one of you has a record sheet with a letter A, B, or C at the top. Every three rounds, at the end of the third, sixth and ninth rounds one of you will take out three balls from three bags, one from each bag. Each bag contains three balls marked with the letters A, B, or C.

If the letter taken out from the first bag coincides with the letter in your record sheet you win in the first round, otherwise you lose the invested amount. If the letter taken out from the second bag coincides with the letter marked in your record sheet you win in the second round and if the letter taken out from the third bag coincides with your letter you win in the third round.

How can I calculate my earnings?

After everybody has chosen the amount to bet in the first three rounds, the three balls will be taken out. In each round, if you win you have to add your invested amount (x) multiplied by 2.5 to the initial endowment of 100 cents. If you lose, you have to deduct the invested amount (x) from the initial endowment (100 cents). We will repeat this process for rounds 4 to 6 and then for rounds 7 to 9. Take note of the three partial results.

At the end of the three blocks you have to add up the partial amounts of the three blocks and this is the total amount you will be paid in cash.

Treatment 3 (T3, HF-AMB)

Welcome to this experiment in decision-making. The experiment will take about 30 minutes. Instructions are very simple and you can earn a sizable amount of money. The money that you earn will be paid in cash at the end of the experiment.

The experiment has nine rounds. In each round you will be endowed with 100 cents (€1). You will be asked to choose the portion x of this amount that you wish to invest in a risky option. This option is the same for the nine rounds.

The risky option: if your investment is successful you will receive 2.5 times the amount you chose to bet. If the investment is unsuccessful you lose the amount you bet.

How do we determine if the investment is successful?

Each one of you has a record sheet with a letter A, B, or C at the top. In each round, one of you will take out a ball from a bag that contains balls marked with the letters A, B, or C. The proportion of each letter is unknown. If the letter chosen coincides with your letter you will win. Otherwise you will lose.

How can I calculate my earnings?

For each round, if you win you have to add your invested amount (x) multiplied by 2.5 to the initial endowment of 100 cents. If you lose, you have to deduct the invested amount (x) from the initial endowment.

At the end of the experiment you have to add up the amounts of the nine rounds and this is the total amount you will be paid in cash.

Treatment 4 (T4, LF-AMB)

Welcome to this experiment in decision-making. The experiment will take about 30 minutes. Instructions are very simple and you can earn a sizable amount of money. The money that you earn will be paid in cash at the end of the experiment.

The experiment has nine rounds divided in blocks of three rounds. In each round you will be endowed with 100 cents (€1). At the beginning of the first round you will be asked to choose the portion x of this amount that you wish to invest in the first, second and third round. In the fourth round you have to choose the amount you wish to invest in the fourth, fifth and sixth rounds. Lastly, in the seventh round, you have to choose the amount for the seventh, eight and ninth rounds.

The risky option: if your investment is successful you will receive 2.5 times the amount you chose to bet. If the investment is unsuccessful you lose the amount you bet.

How do we determine if the investment is successful?

Each one of you has a record sheet with a letter A, B, or C at the top. Every three rounds, at the end of the third, sixth and ninth rounds one of you will take out three balls from three bags, one from each bag. Each bag contains balls marked with the letters A, B, or C. The proportion of each letter is unknown.

If the letter taken out from the first bag coincides with the letter in your record sheet you win in the first round, otherwise you lose the invested amount. If the letter taken out from the second bag coincides with the letter marked in your record sheet you win in the second round and if the letter taken out from the third bag coincides with your letter you win in the third round.

How can I calculate my earnings?

After everybody has chosen the amount to bet in the first three rounds, the three balls will be taken out. In each round, if you win you have to add your invested amount (x) multiplied by 2.5 to the initial endowment of 100 cents. If you lose, you have to deduct the invested amount (x) from the initial endowment (100 cents). We will repeat this process for rounds 4 to 6 and then for rounds 7 to 9. Take note of the three partial results.

At the end of the three blocks you have to add up the partial amounts of the three blocks and this is the total amount you will be paid in cash.

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