Online appendix of "Searching for the Reference Point"

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Contents

1 Description of the online appendix

In section 6.4 of the paper, we describe the robustness checks that we performed, varying the utility and weighting functions and the model specification. Table 6 of the paper describes the various specifications and is recalled below.

Model	Choice-specific reference point		Prospect-specific reference point	
	Consumption utility	Probability weghting	Consumption utility	Probability weghting
1	Yes	Yes	Yes	Yes
2	No	Yes	Yes	Yes
3	Yes	Yes	Yes	No
4	No	Yes	Yes	No
5	Yes	No	Yes	No
6	No	No	Yes	No

Table 1: Considered Models

Model 1 is our benchmark model, in which probability weighting and consumption utility are present for all reference point rules. Section 2 reports the results we obtained for this model, and are described in detail in the paper. Sections 3 to 5 report the results obtained with the same specification as Model 1 but with parametric variations:

- Exponential utility on log scale[1]

$$U(x) = \begin{cases} \frac{1-\alpha^x}{1-\alpha} & \text{if } \alpha \neq 1 \\ x & \text{if } \alpha = 1 \end{cases}$$

- Prelec's two-parameter weighting function $w(p) = exp(-\gamma_2(-ln(p))^{\gamma_1})$,

- *IBeta* weighting function $w(p) = \frac{\int_0^p t^{\gamma_1 - 1}(1-t)^{\gamma_2 - 1}\,\mathrm{d}t.}{\int_0^1 t^{\gamma_1 - 1}(1-t)^{\gamma_2 - 1}\,\mathrm{d}t}$ is the cumulative distribution function of the Beta probability distribution. An illustration of the possible shapes of this family is provided in Appendix B of the main text.

Sections 6 to 8 report the results obtained for Models 2, 3, and 4 (with power utility and Prelec's one-parameter weighting function as in the benchmark model). The results of Models 5 and 6 (no weighting function) were unstable and are therefore not reported.

Each section describes one model and consists of two subsections. The first subsection describes the behavioral parameters, starting with the behavioral population-level parameters. The first figure represents the posterior densities of the population parameters. A table reports their point estimates, which can be compared with those displayed in Figures 6 and 7 in the paper. For comparison with the main text we also report the estimates for Subject 17 with the equivalent of Figure 8.

The second subsection reports the results for the reference points. The first figure is the equivalent of Figure 3 in the paper. It is followed by a table that is the equivalent of Table

[1]This is a re-parameterization of standard normalised exponential utility:

$$U(x) = \begin{cases} \frac{1-exp(\beta * x)}{1-exp(\beta)} & \text{if } \beta \neq 0 \\ x & \text{if } \beta = 0 \end{cases}$$

where the parameter $\beta \in (-\infty, +\infty)$ is re-parameterized as $\beta = log(\alpha)$ with $\alpha \in (0, +\infty)$. In this parameterization α has the same range and interpretation as the α parameter for the power utility, thus, allowing for the same probabilistic specification of the hierarchical model across the two families.

2. The second figure is the equivalent of Figure 4 in the paper. A table follows which can be compared with the data of Figure 5 in the paper. The last table is the equivalent of Table 4 in the paper.

Section 9 displays the instructions of the experiment. Section 10 shows that the results of Abeler et al. are consistent with the Maxmin rule.

2 Model 1: Benchmark

2.1 Behavioral Parameters

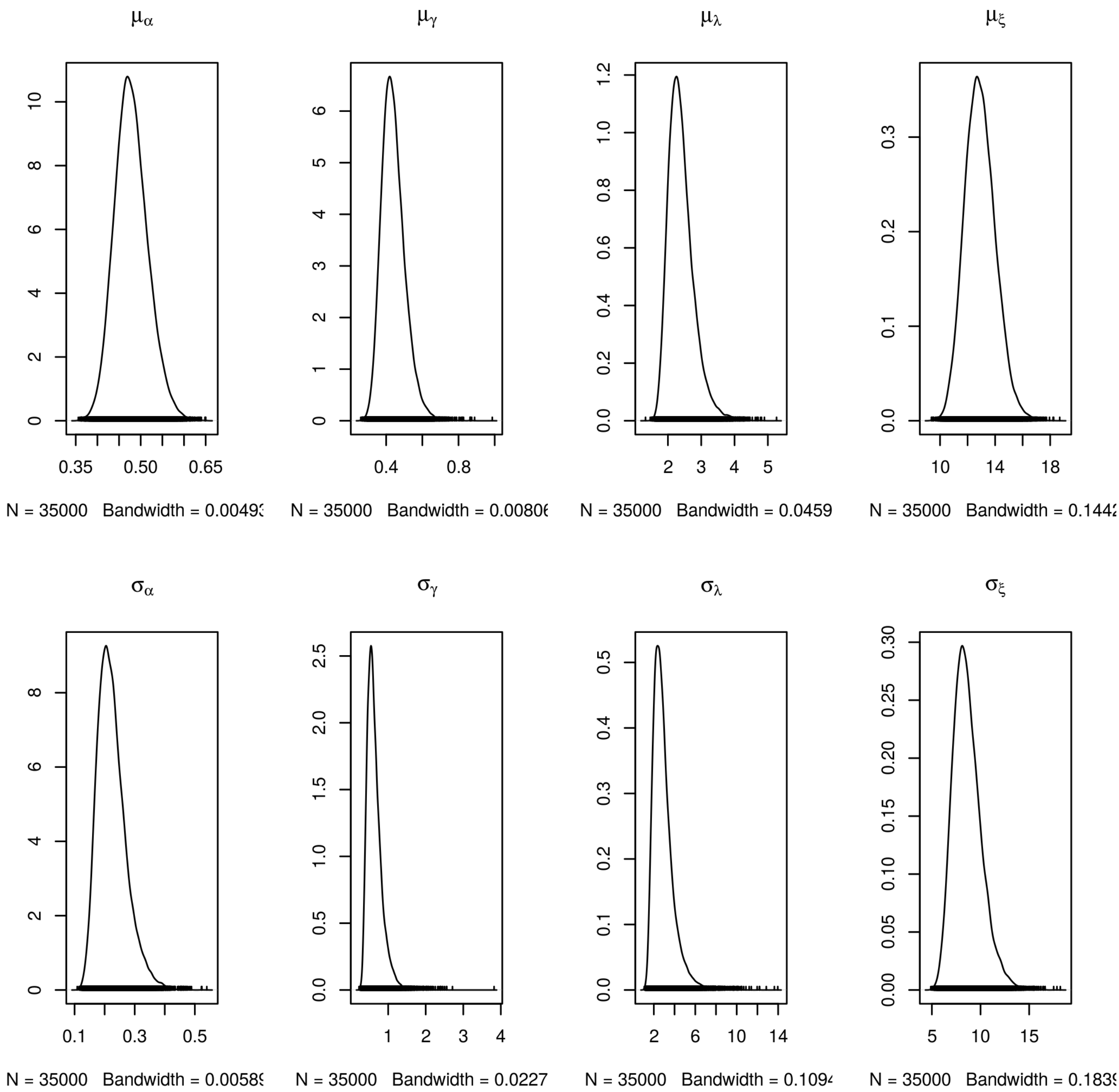


Figure 1: Posterior densities of behavioral parameters in population.

	μ	σ
α	0.48	0.22
γ	0.43	0.59
λ	2.34	2.69
ξ	12.85	8.46

Table 2: Posterior point estimates of behavioral parameters in population: α - exponent of power utility, γ - parameter of Prelec weighting function, λ - loss aversion.

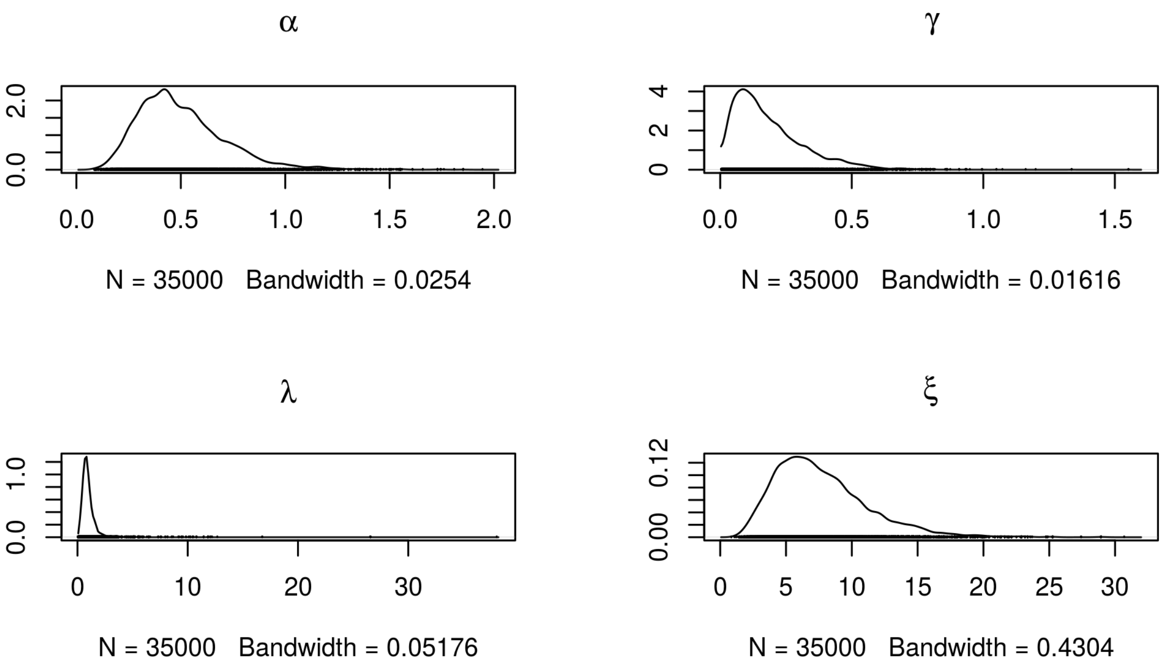


Figure 2: Posterior densities of behavioral parameters for subject 17 (B_{17})

	Median	SD
α	0.46	0.21
γ	0.15	0.14
λ	0.84	0.84
ξ	7.03	3.55

Table 3: Posterior summaries for subject 17.

2.2 Reference Points

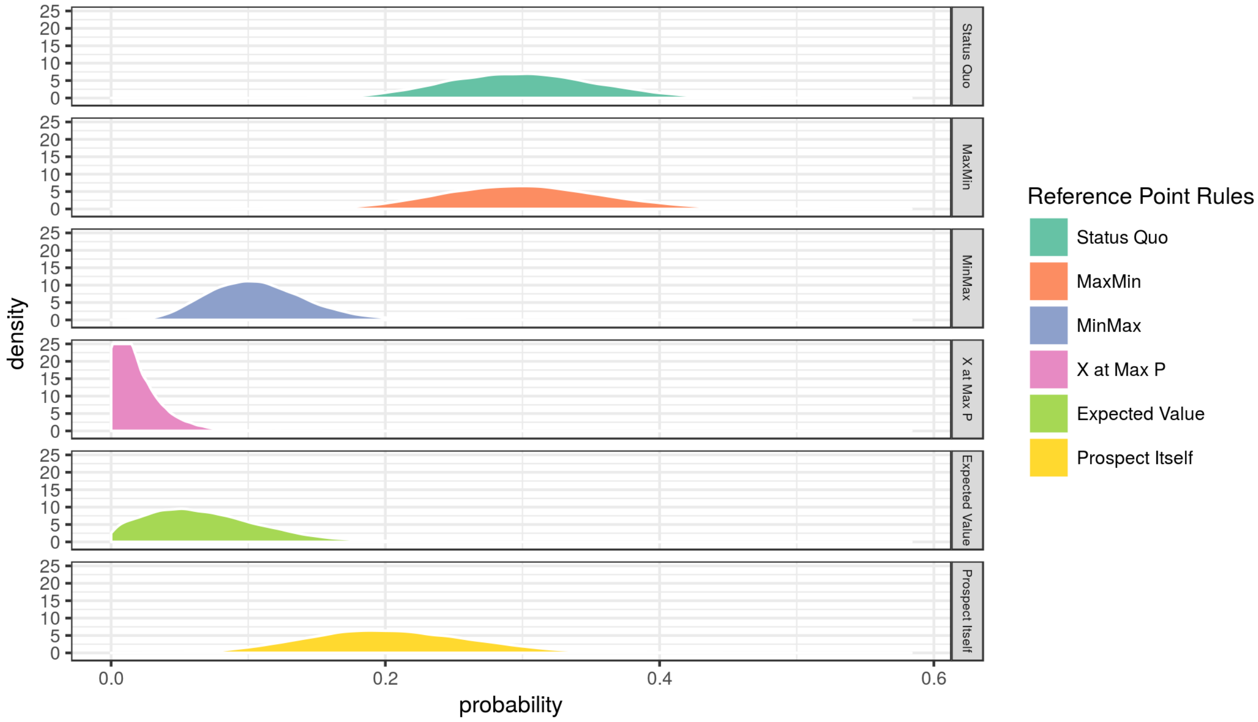


Figure 3: Posterior densities for RP rules in population

	Median	SD
Status Quo	0.30	0.06
MaxMin	0.30	0.06
MinMax	0.10	0.04
X at Max P	0.01	0.02
Expected Value	0.06	0.04
Prospect Itself	0.20	0.06

Table 4: Point estimates of RP mixture in population.

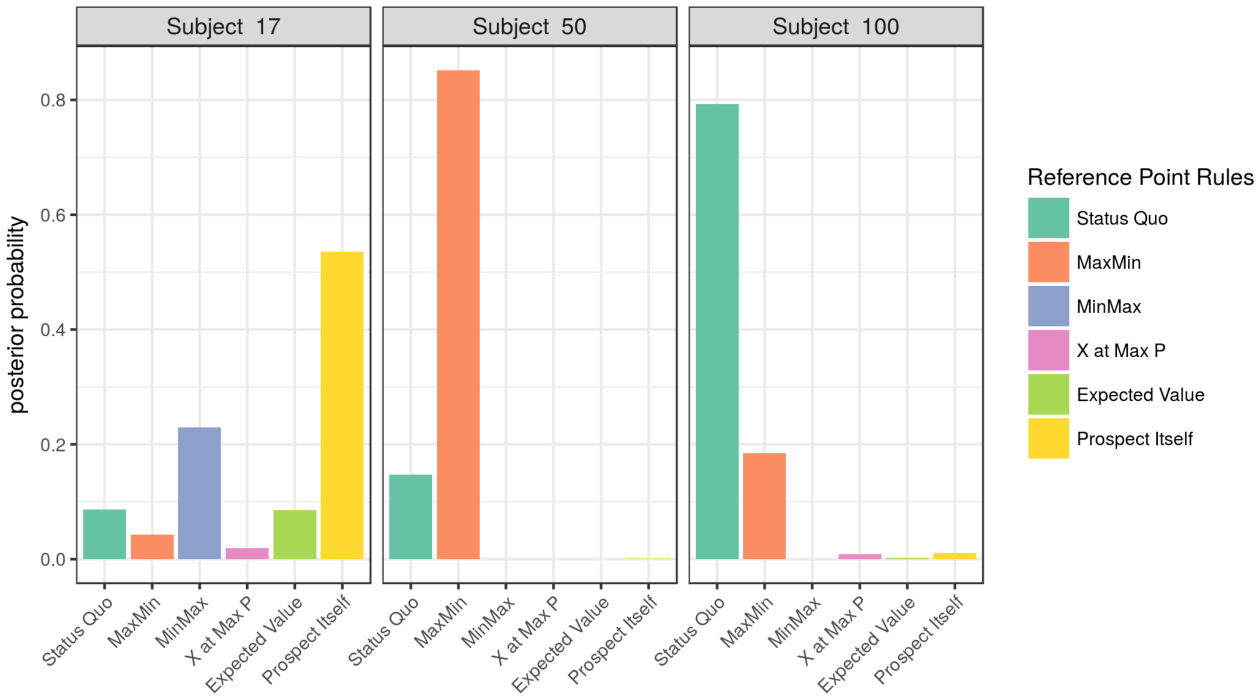


Figure 4: Posterior probability of a selection of subjects using a particular model

	Nr
Status Quo	43
MaxMin	33
MinMax	10
X at Max P	0
Expected Value	2
Prospect Itself	19

Table 5: Sharp predictions. Number of subjects for which the posterior probability of the respective reference point is higher than 0.5.

	α	γ	λ	ξ	Nr
MinMax	0.40	0.15	0.50	14.34	10
Status Quo	0.42	0.28	1.51	11.75	43
MaxMin	0.46	0.24	2.24	10.30	33
Expected Value	0.36	0.25	2.44	6.14	2
Prospect Itself	0.45	0.16	2.23	10.89	19
other	0.50	0.25	1.36	10.06	32
ALL	0.44	0.24	1.59	10.89	139

Table 6: Median individual level parameters for each sharply clasified group.

The previous table is Table 4 in the paper.

Table 7: EU test for individuals sharply classified as using Status Quo rule. Confidence level 0.05%

	γ			
	< 1	1	> 1	Sum
α				
< 1	28	9	0	37
1	3	3	0	6
> 1	0	0	0	0
Sum	31	12	0	43

3 Model 1 with Exponential Utility

3.1 Behavioral Parameters

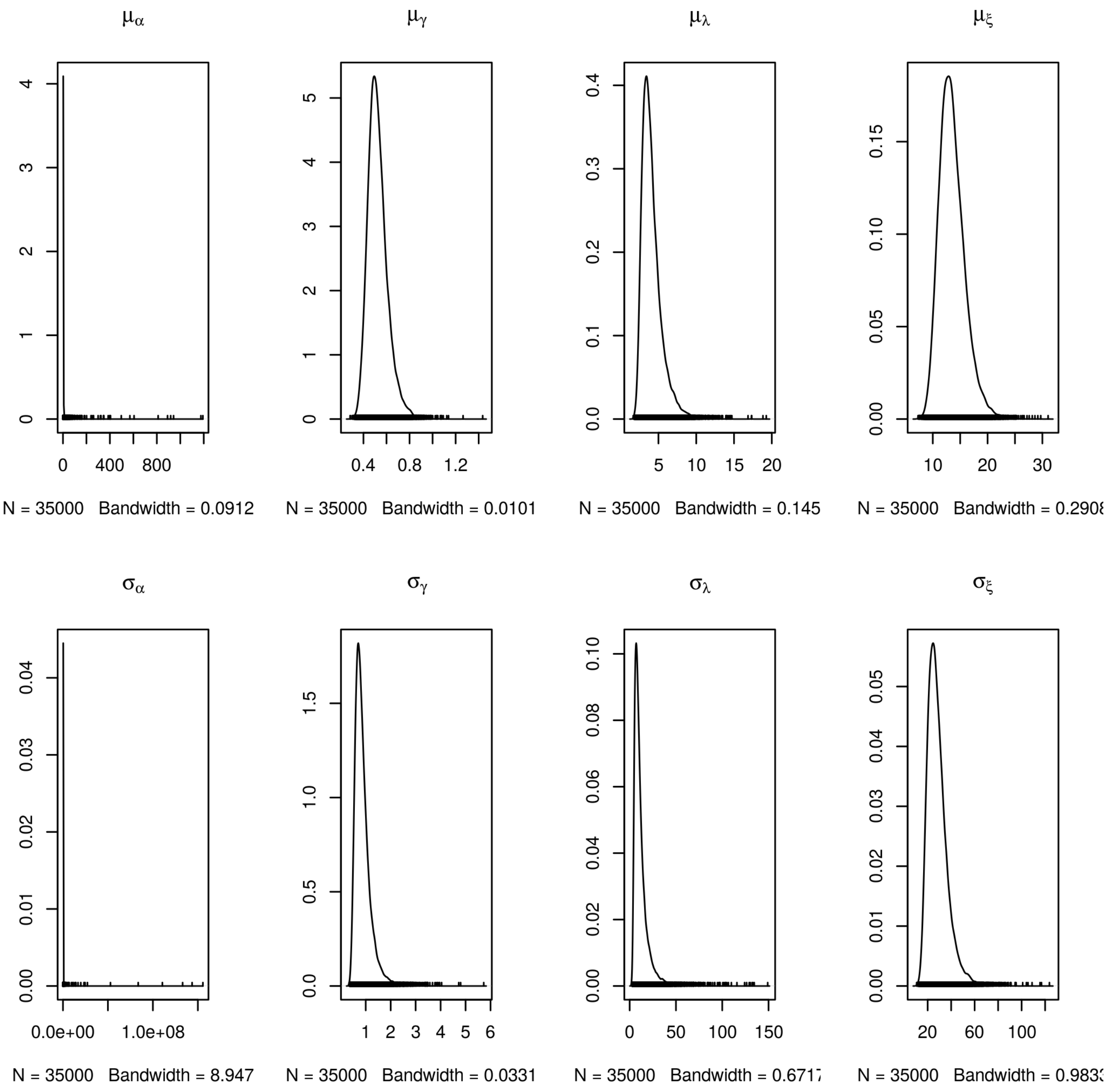


Figure 5: Posterior densities of behavioral parameters in population.

	μ	σ
α	0.62	21.05
γ	0.51	0.80
λ	3.81	9.40
ξ	13.25	26.80

Table 8: Posterior point estimates of behavioral parameters in population: α - exponent of power utility, γ - parameter of Prelec weighting function, λ - loss aversion.

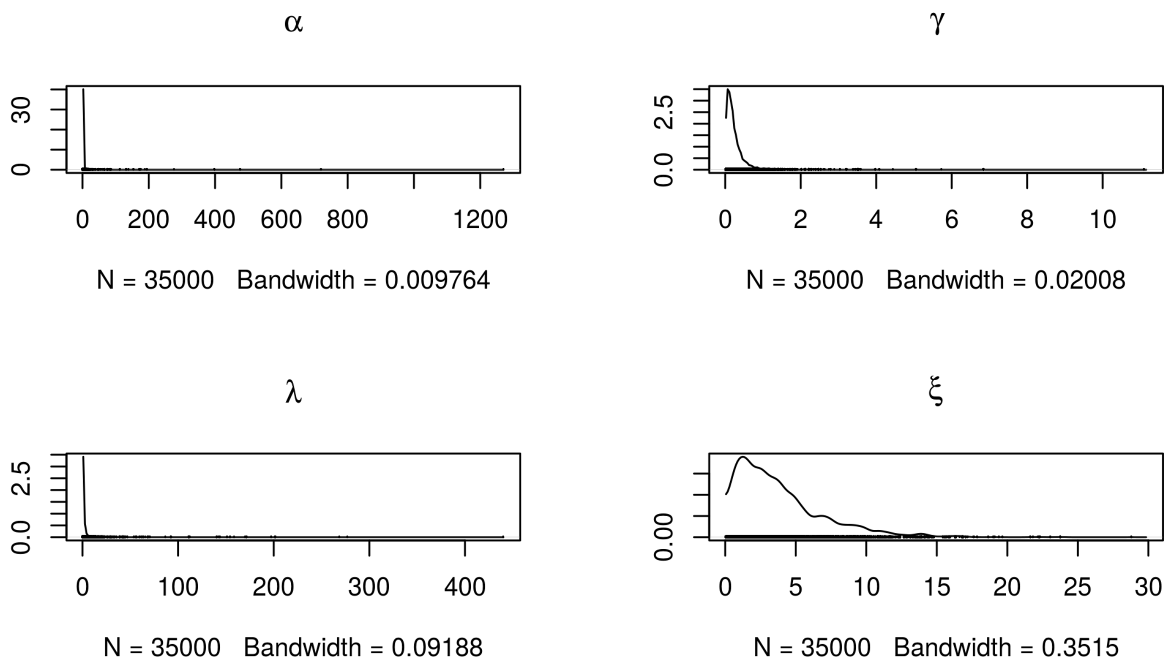


Figure 6: Posterior densities of behavioral parameters for subject 17 (B_{17})

	Median	SD
α	0.02	11.58
γ	0.17	0.32
λ	0.78	7.35
ξ	3.10	3.12

Table 9: Posterior summaries for subject 17.

3.2 Reference Points

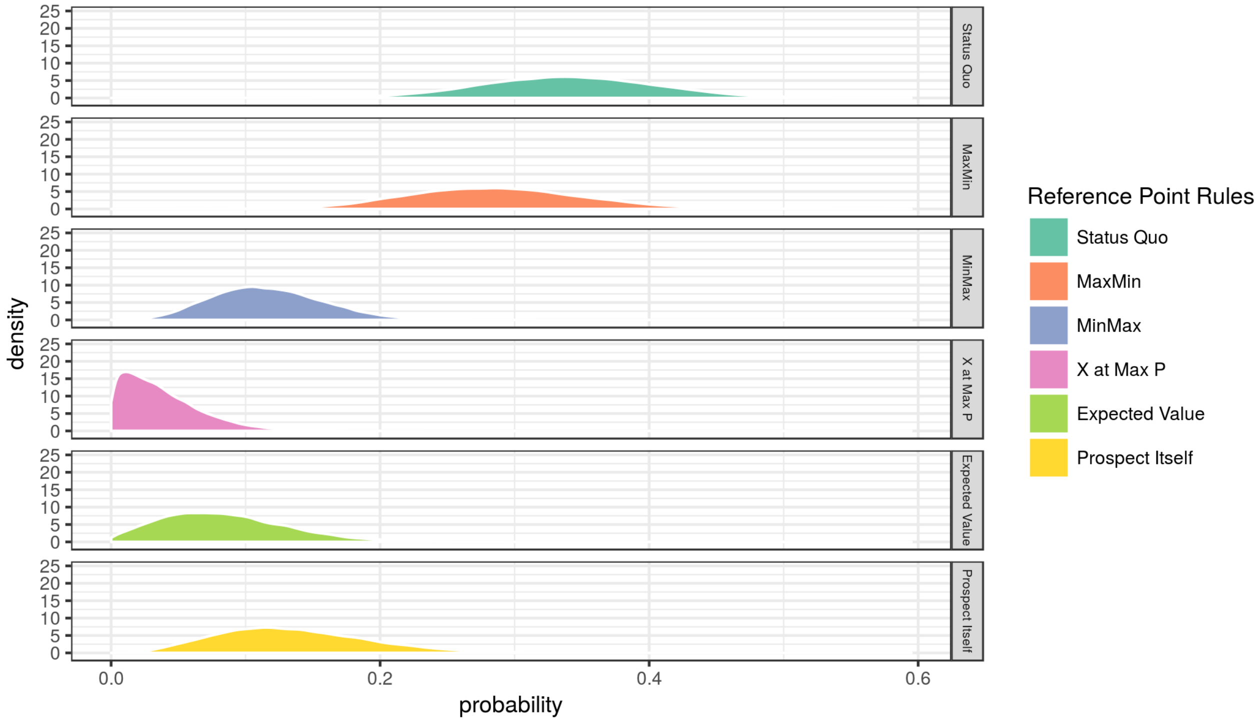


Figure 7: Posterior densities for RP rules in population

	Median	SD
Status Quo	0.34	0.06
MaxMin	0.28	0.07
MinMax	0.11	0.04
X at Max P	0.03	0.03
Expected Value	0.08	0.05
Prospect Itself	0.13	0.05

Table 10: Point estimates of RP mixture in population.

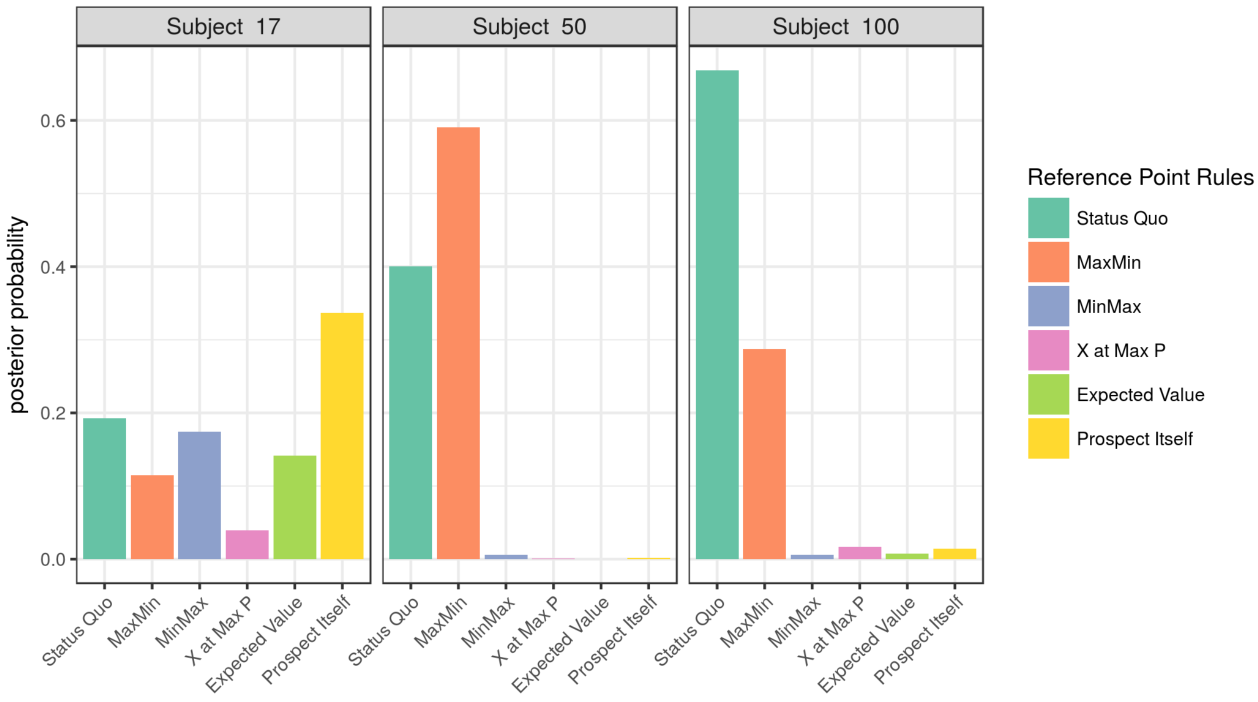


Figure 8: Posterior probability of a selection of subjects using a particular model

	Nr
Status Quo	45
MaxMin	30
MinMax	10
X at Max P	0
Expected Value	3
Prospect Itself	7

Table 11: Sharp predictions. Number of subjects for which the posterior probability of the respective reference point is higher than 0.5.

	α	γ	λ	ξ	Nr
MinMax	0.01	0.16	0.38	11.30	10
Status Quo	0.02	0.29	1.51	9.81	45
MaxMin	0.02	0.23	2.70	8.12	30
Prospect Itself	0.01	0.17	5.96	4.91	7
Expected Value	0.01	1.07	2.28	12.26	3
other	0.03	0.24	1.39	6.48	44
ALL	0.02	0.26	1.68	8.31	139

Table 12: Median individual level parameters for each sharply clasified group.

4 Model 1 with Prelec's Two-Parameter Weighting Function

4.1 Behavioral Parameters

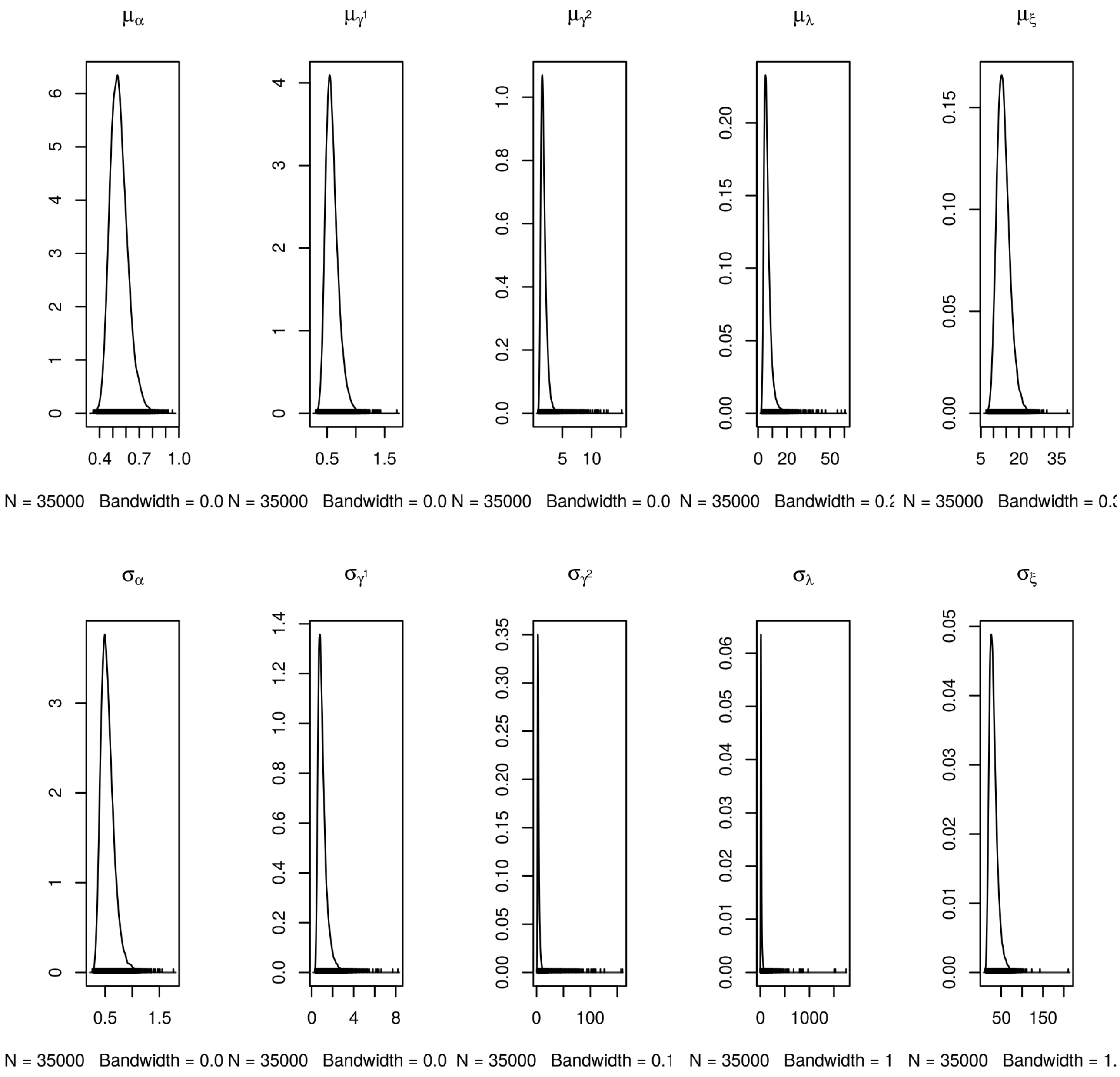


Figure 9: Posterior densities of behavioral parameters in population.

	μ	σ
α	0.54	0.53
γ^1	0.57	0.92
γ^2	1.72	3.08
λ	5.86	15.23
ξ	13.67	29.72

Table 13: Posterior point estimates of behavioral parameters in population: α - exponent of power utility, γ - parameter of Prelec weighting function, λ - loss aversion.

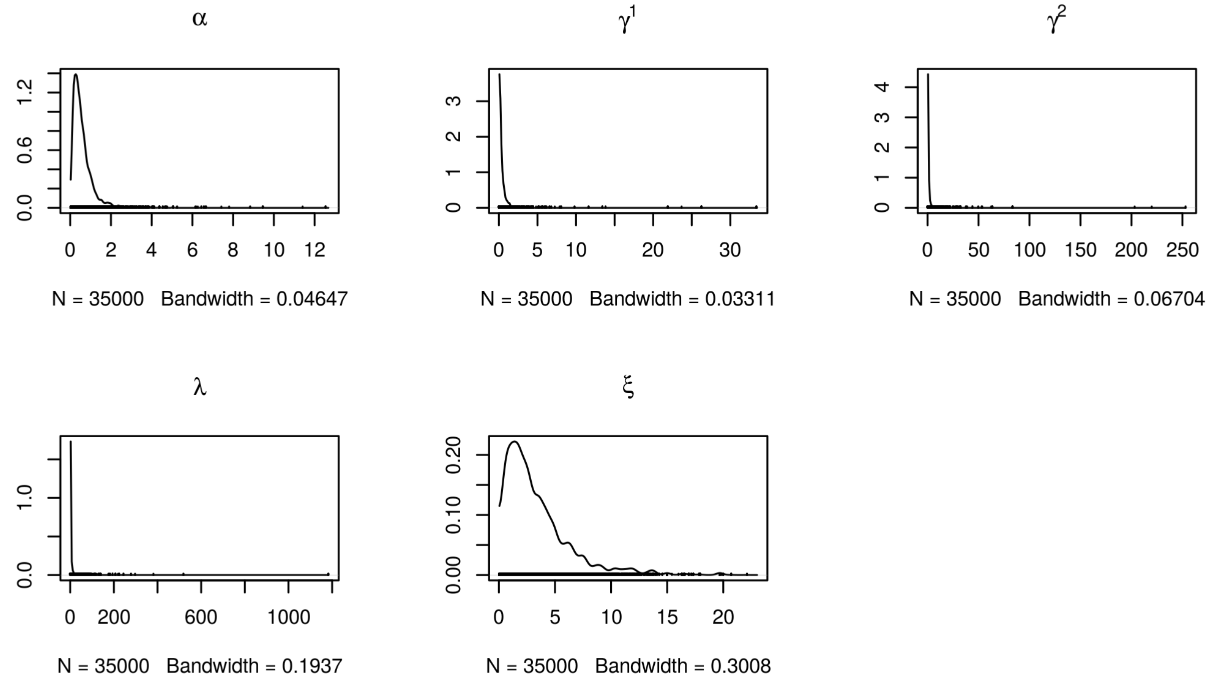


Figure 10: Posterior densities of behavioral parameters for subject 17 (B_{17})

	Median	SD
α	0.46	0.56
γ^1	0.22	0.87
γ^2	0.46	3.87
λ	1.04	15.48
ξ	2.56	2.90

Table 14: Posterior summaries for subject 17.

4.2 Reference Points

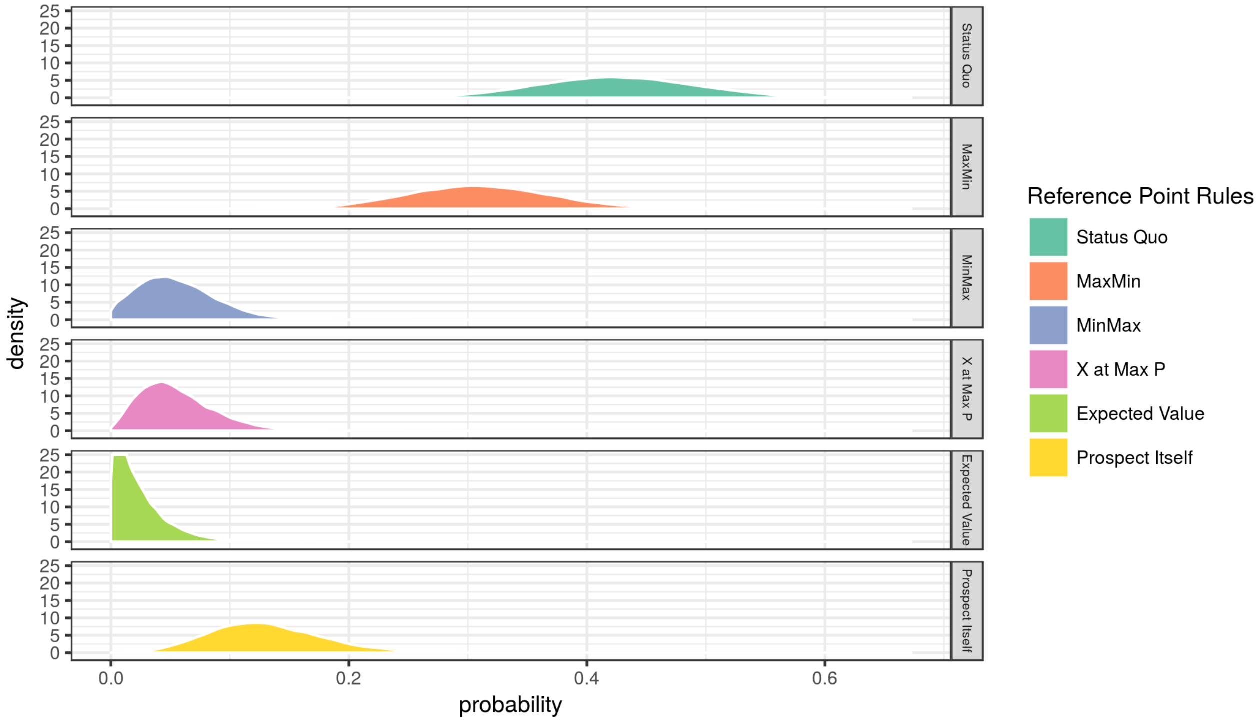


Figure 11: Posterior densities for RP rules in population

	Median	SD
Status Quo	0.42	0.07
MaxMin	0.31	0.06
MinMax	0.05	0.03
X at Max P	0.05	0.03
Expected Value	0.02	0.02
Prospect Itself	0.13	0.05

Table 15: Point estimates of RP mixture in population.

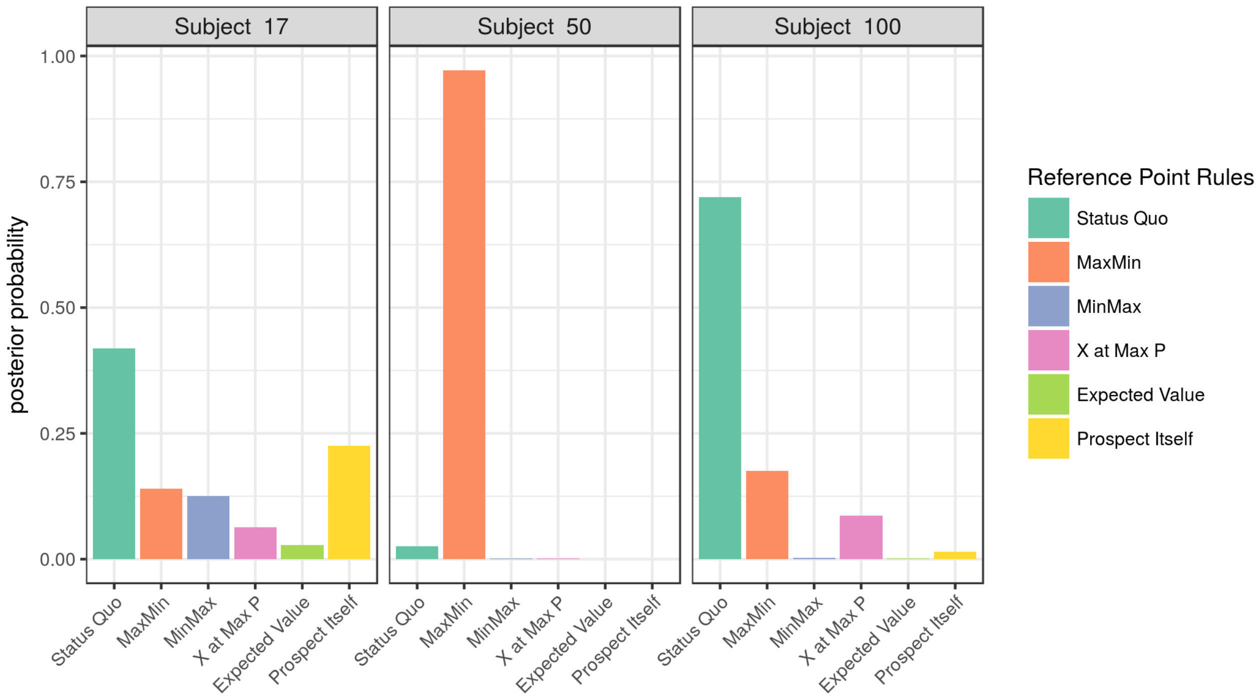


Figure 12: Posterior probability of a selection of subjects using a particular model

	Nr
Status Quo	65
MaxMin	31
MinMax	3
X at Max P	3
Expected Value	0
Prospect Itself	8

Table 16: Sharp predictions. Number of subjects for which the posterior probability of the respective reference point is higher than 0.5.

	α	γ^1	γ^2	λ	ξ	Nr
Status Quo	0.39	0.28	1.17	1.99	10.92	65
MinMax	0.36	0.18	0.29	1.05	10.40	3
MaxMin	0.41	0.22	0.59	2.75	7.02	31
Prospect Itself	0.36	0.45	0.64	6.47	4.01	8
X at Max P	0.30	0.65	2.75	2.94	5.81	3
other	0.46	0.29	1.36	3.36	7.06	29
ALL	0.40	0.27	0.96	2.30	7.82	139

Table 17: Median individual level parameters for each sharply clasified group.

5 Model 1 with *IBeta* Weighting Function

5.1 Behavioral Parameters

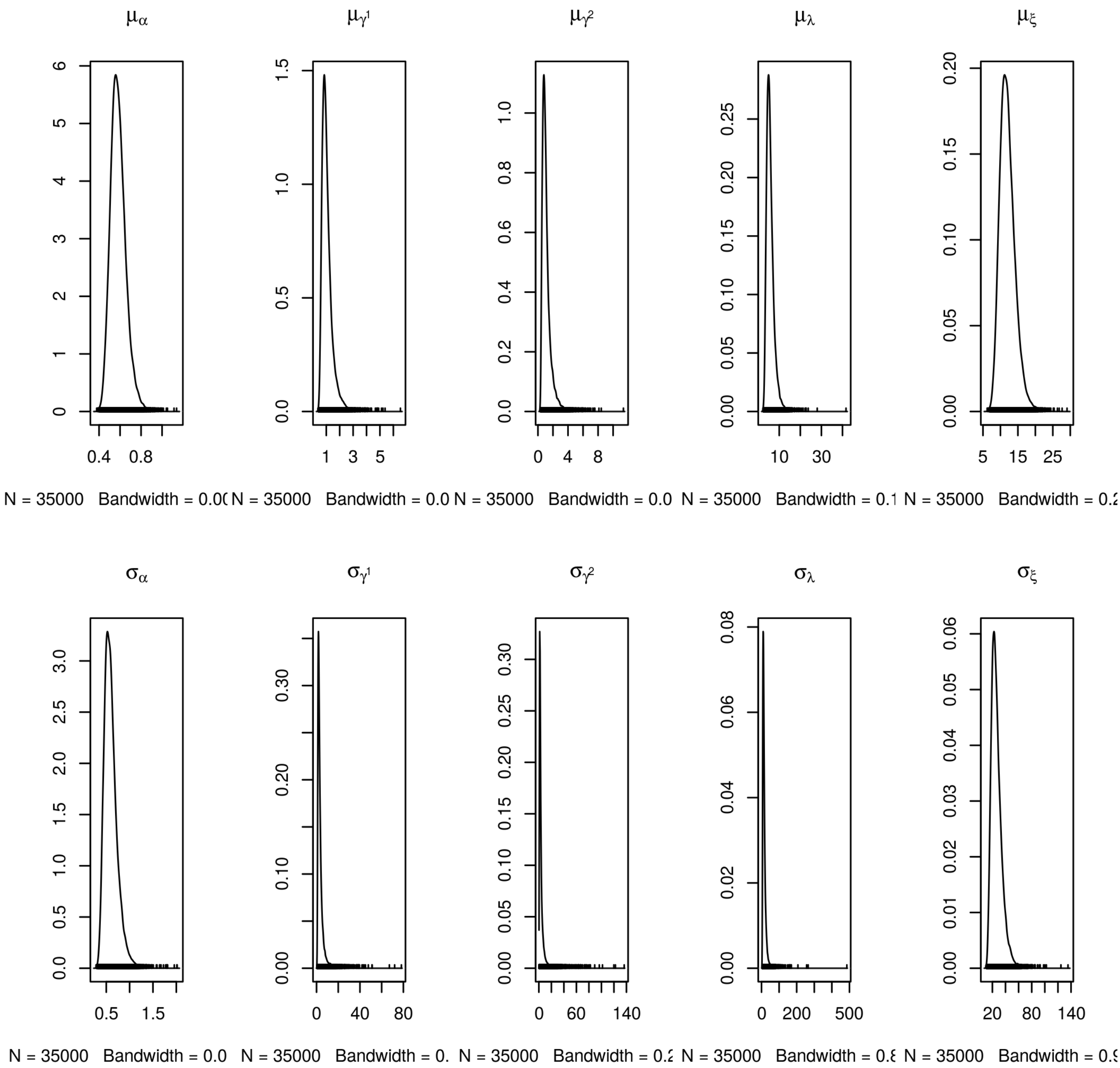


Figure 13: Posterior densities of behavioral parameters in population.

	μ	σ
α	0.58	0.58
γ^1	0.96	2.50
γ^2	0.96	2.29
λ	5.39	12.47
ξ	11.76	24.89

Table 18: Posterior point estimates of behavioral parameters in population: α - exponent of power utility, γ - parameter of Prelec weighting function, λ - loss aversion.

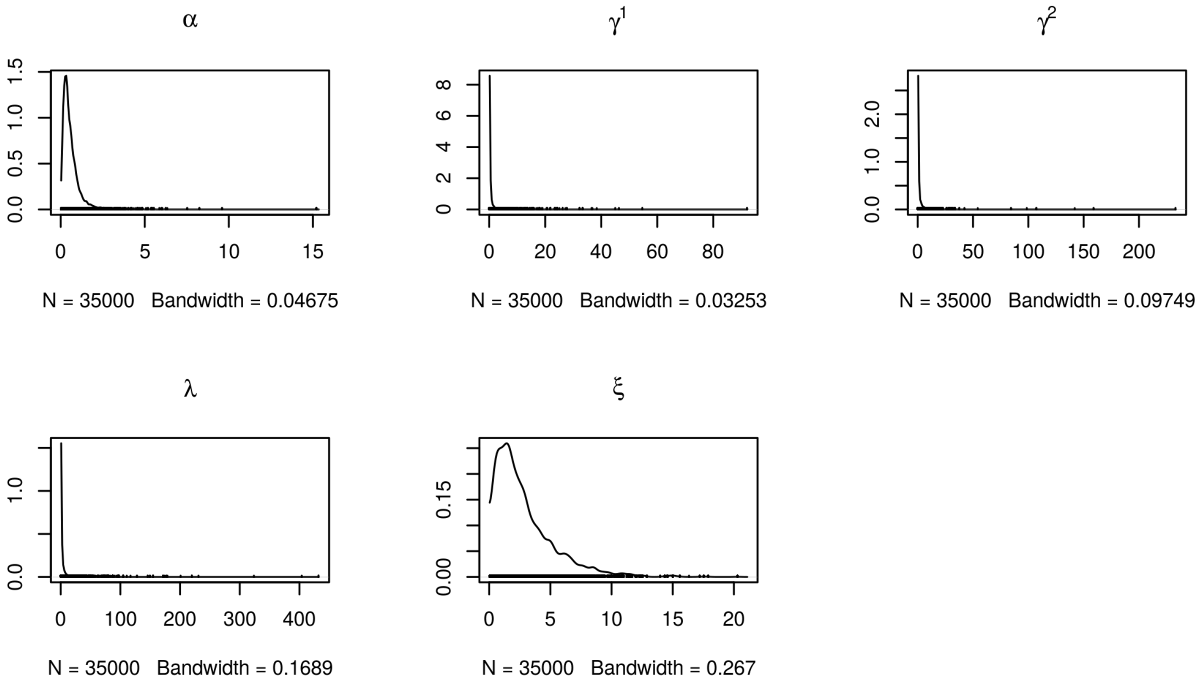


Figure 14: Posterior densities of behavioral parameters for subject 17 (B_{17})

	Median	SD
α	0.45	0.60
γ^1	0.17	2.12
γ^2	0.41	4.10
λ	1.01	9.51
ξ	2.17	2.42

Table 19: Posterior summaries for subject 17.

5.2 Reference Points

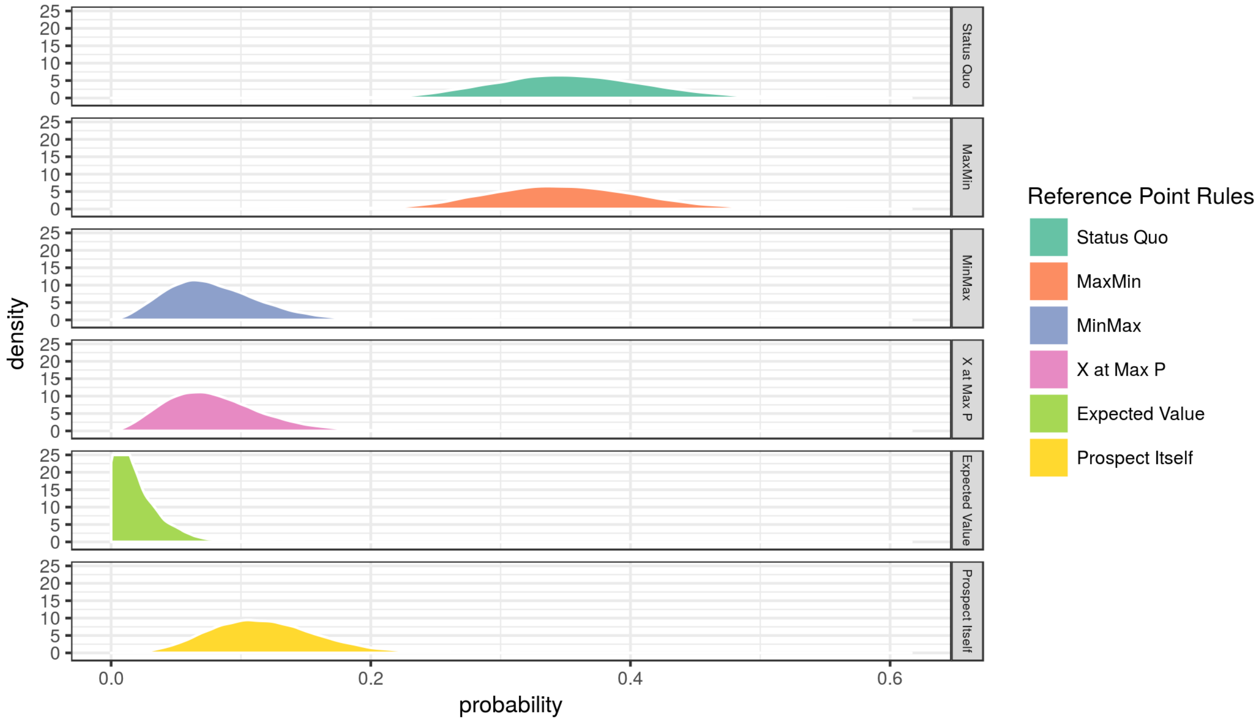


Figure 15: Posterior densities for RP rules in population

	Median	SD
Status Quo	0.35	0.06
MaxMin	0.35	0.06
MinMax	0.07	0.04
X at Max P	0.08	0.04
Expected Value	0.01	0.02
Prospect Itself	0.12	0.04

Table 20: Point estimates of RP mixture in population.

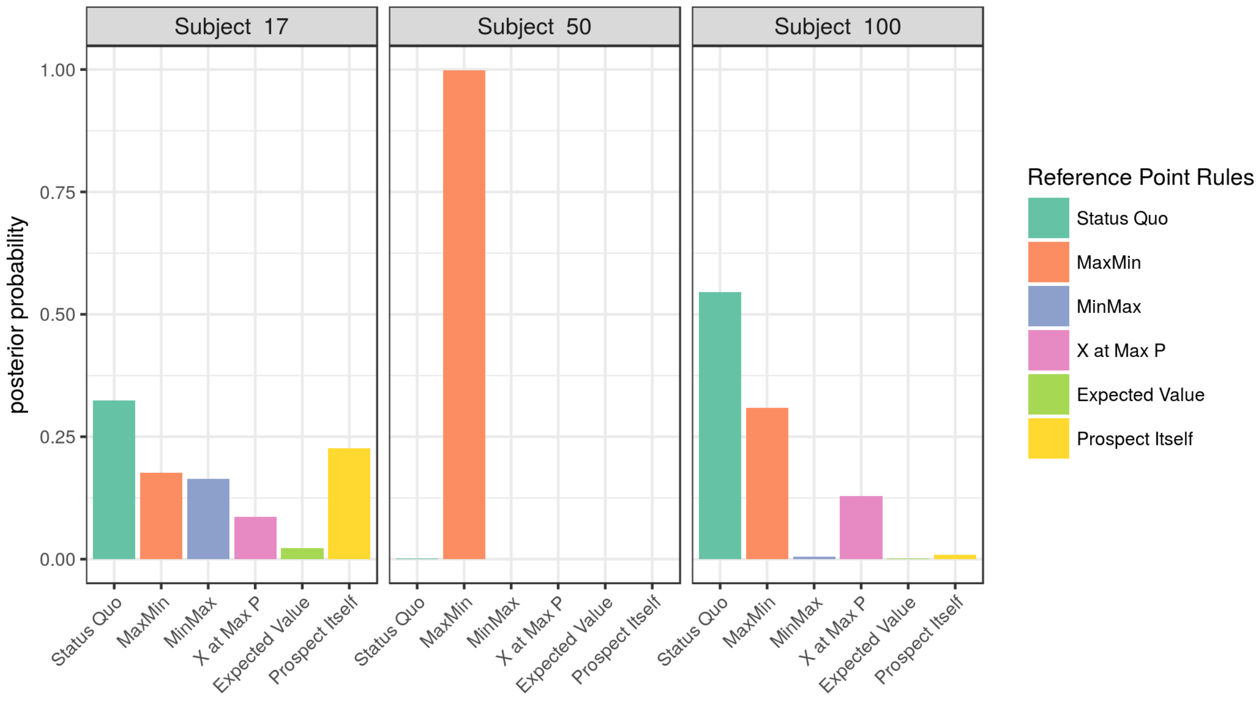


Figure 16: Posterior probability of a selection of subjects using a particular model

	Nr
Status Quo	52
MaxMin	40
MinMax	3
X at Max P	6
Expected Value	0
Prospect Itself	8

Table 21: Sharp predictions. Number of subjects for which the posterior probability of the respective reference point is higher than 0.5.

	α	γ^1	γ^2	λ	ξ	Nr
Status Quo	0.39	0.46	0.26	1.96	9.75	52
MaxMin	0.44	0.19	0.33	2.88	5.58	40
X at Max P	0.40	1.15	0.41	4.64	5.85	6
Prospect Itself	0.35	0.14	0.54	4.83	5.26	8
MinMax	0.35	0.10	0.84	1.07	9.40	3
other	0.49	0.41	0.27	1.90	4.77	30
ALL	0.42	0.33	0.30	2.27	6.48	139

Table 22: Median individual level parameters for each sharply clasified group.

6 Model 2

6.1 Behavioral Parameters

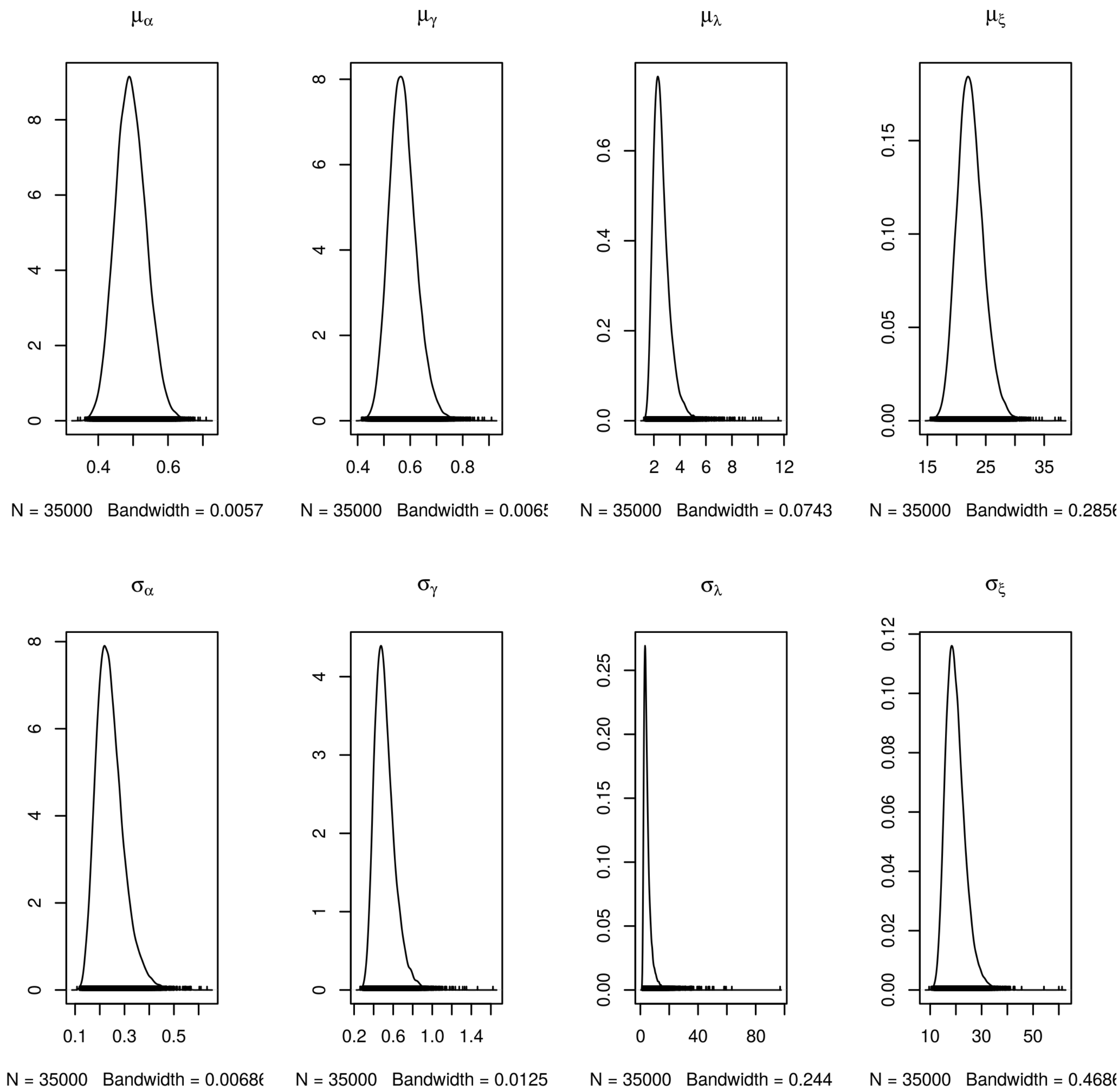


Figure 17: Posterior densities of behavioral parameters in population.

	μ	σ
α	0.49	0.23
γ	0.57	0.50
λ	2.47	4.03
ξ	22.24	19.37

Table 23: Posterior point estimates of behavioral parameters in population: α - exponent of power utility, γ - parameter of Prelec weighting function, λ - loss aversion.

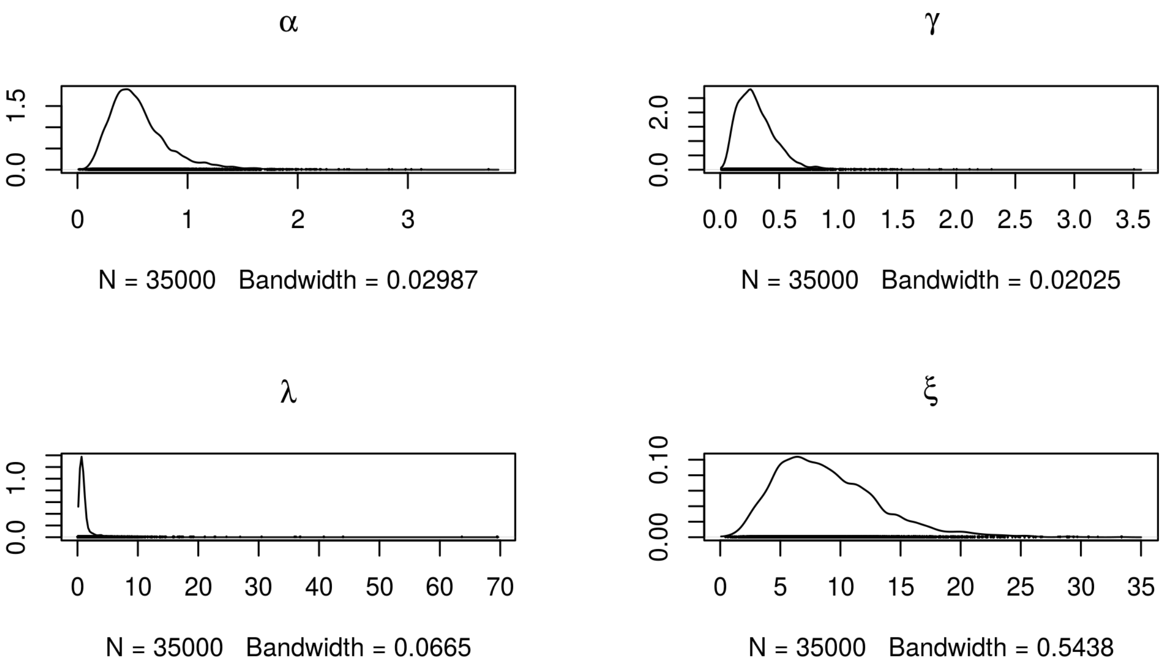


Figure 18: Posterior densities of behavioral parameters for subject 17 (B_{17})

	Median	SD
α	0.50	0.29
γ	0.28	0.18
λ	0.80	2.17
ξ	8.24	4.33

Table 24: Posterior summaries for subject 17.

6.2 Reference Points

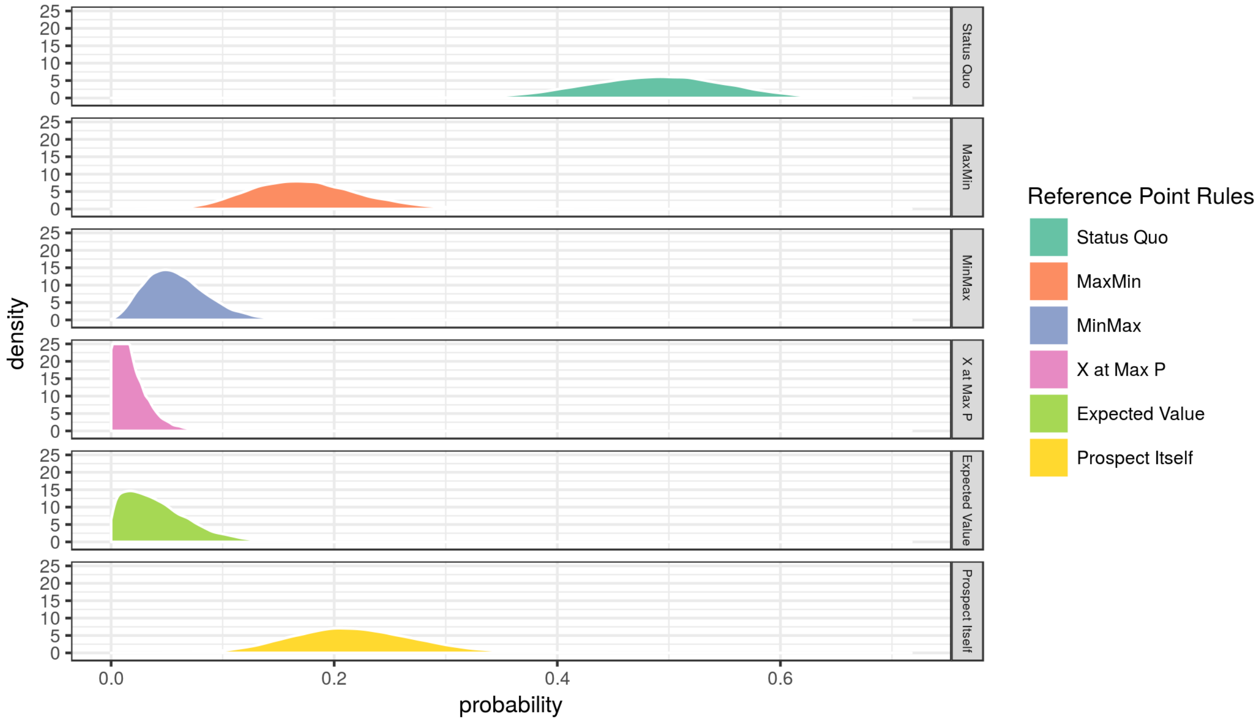


Figure 19: Posterior densities for RP rules in population

	Median	SD
Status Quo	0.49	0.06
MaxMin	0.17	0.05
MinMax	0.06	0.03
X at Max P	0.01	0.01
Expected Value	0.04	0.03
Prospect Itself	0.22	0.06

Table 25: Point estimates of RP mixture in population.

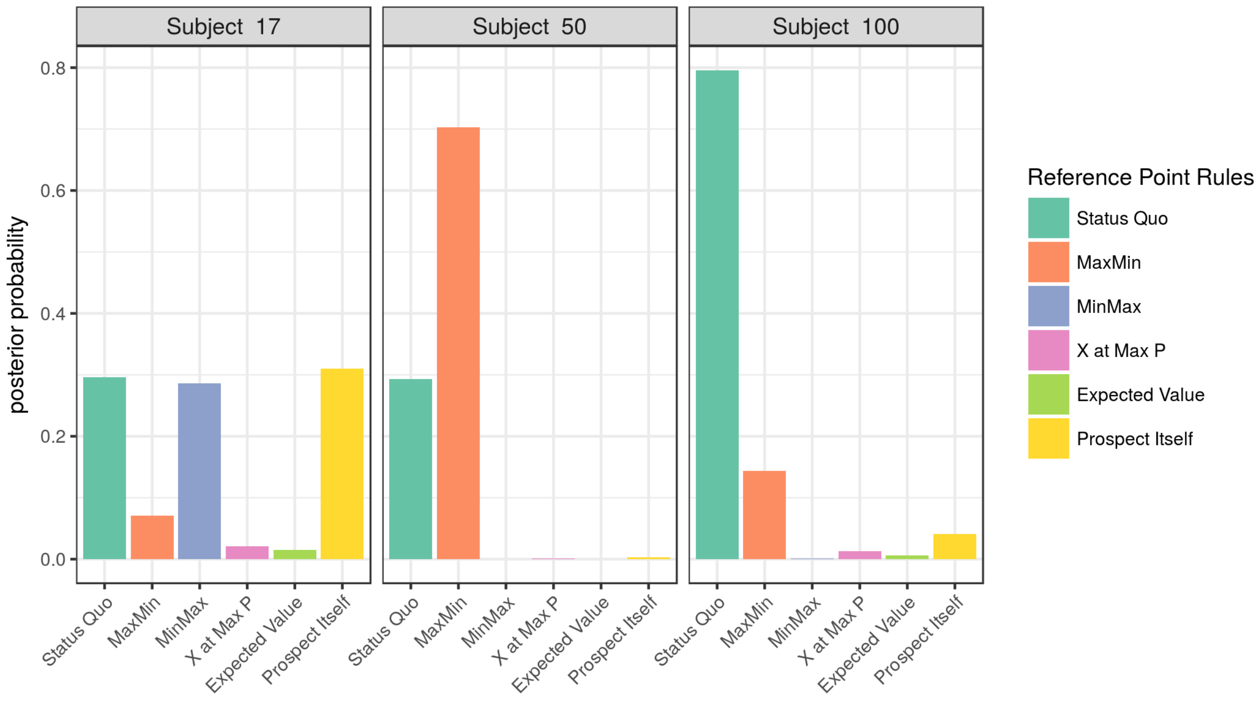


Figure 20: Posterior probability of a selection of subjects using a particular model

	Nr
Status Quo	74
MaxMin	18
MinMax	4
X at Max P	0
Expected Value	0
Prospect Itself	21

Table 26: Sharp predictions. Number of subjects for which the posterior probability of the respective reference point is higher than 0.5.

	α	γ	λ	ξ	Nr
Prospect Itself	0.46	0.35	0.73	18.68	21
Status Quo	0.43	0.47	1.36	19.38	74
MinMax	0.43	0.25	0.56	22.56	4
MaxMin	0.44	0.37	1.96	15.04	18
other	0.50	0.50	1.58	10.80	22
ALL	0.46	0.46	1.41	16.54	139

Table 27: Median individual level parameters for each sharply clasified group.

7 Model 3

7.1 Behavioral Parameters

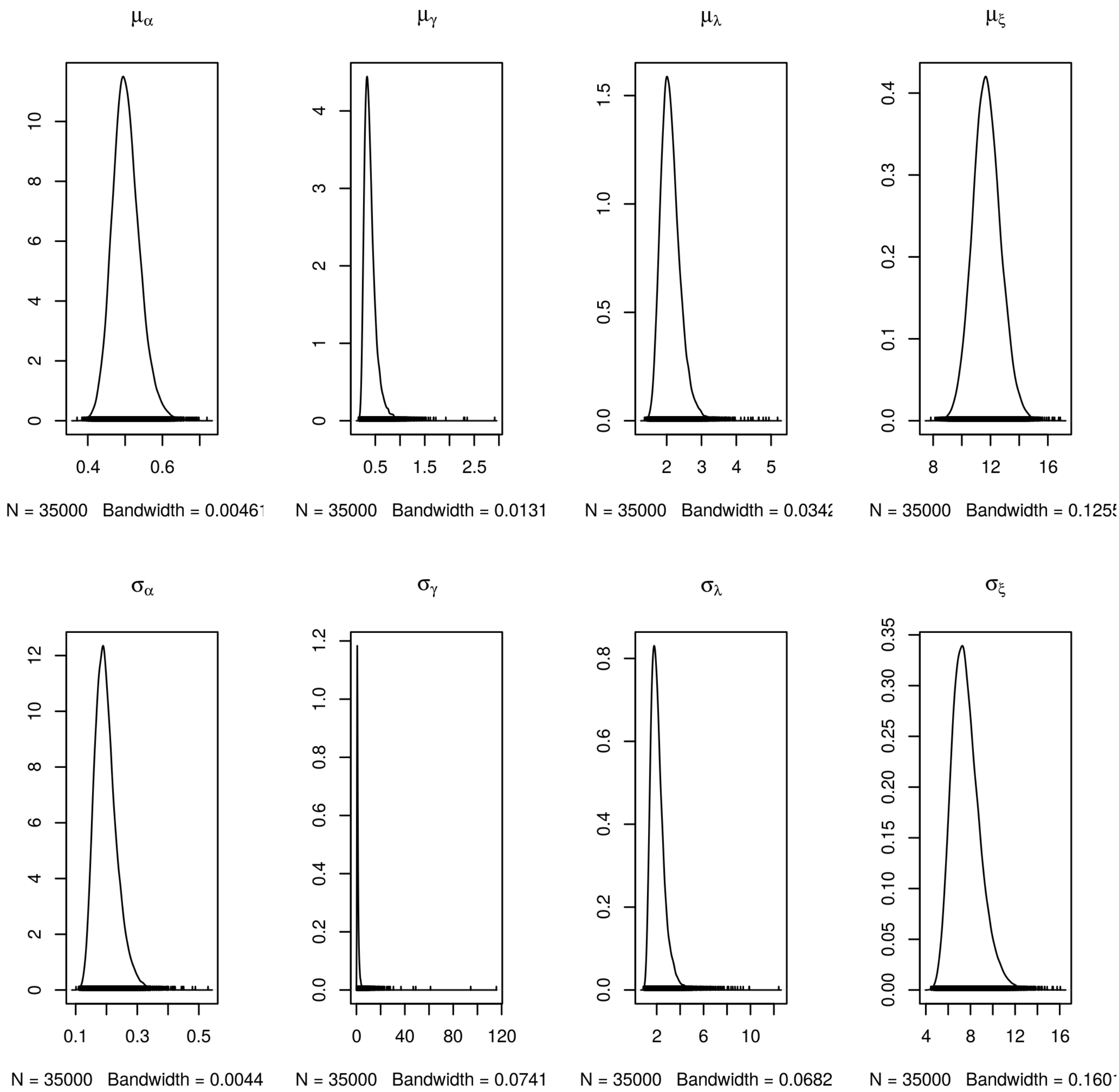


Figure 21: Posterior densities of behavioral parameters in population.

	μ	σ
α	0.50	0.19
γ	0.37	0.89
λ	2.08	1.97
ξ	11.70	7.45

Table 28: Posterior point estimates of behavioral parameters in population: α - exponent of power utility, γ - parameter of Prelec weighting function, λ - loss aversion.

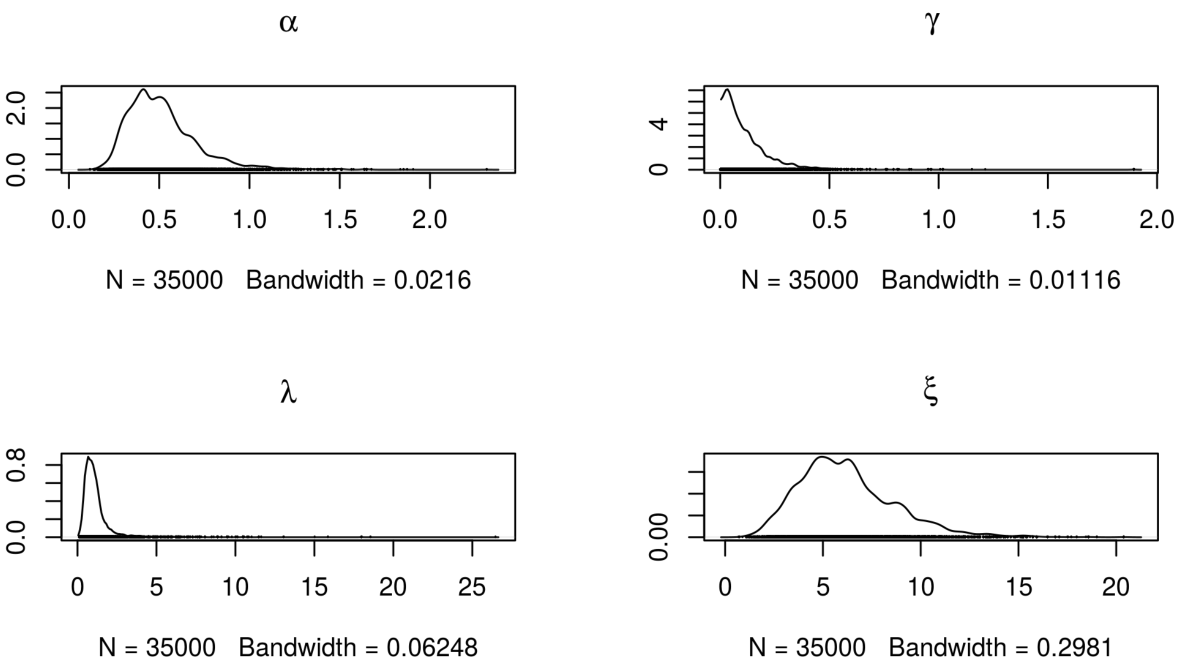


Figure 22: Posterior densities of behavioral parameters for subject 17 (B_{17})

	Median	SD
α	0.48	0.20
γ	0.08	0.11
λ	0.94	1.02
ξ	5.90	2.46

Table 29: Posterior summaries for subject 17.

7.2 Reference Points

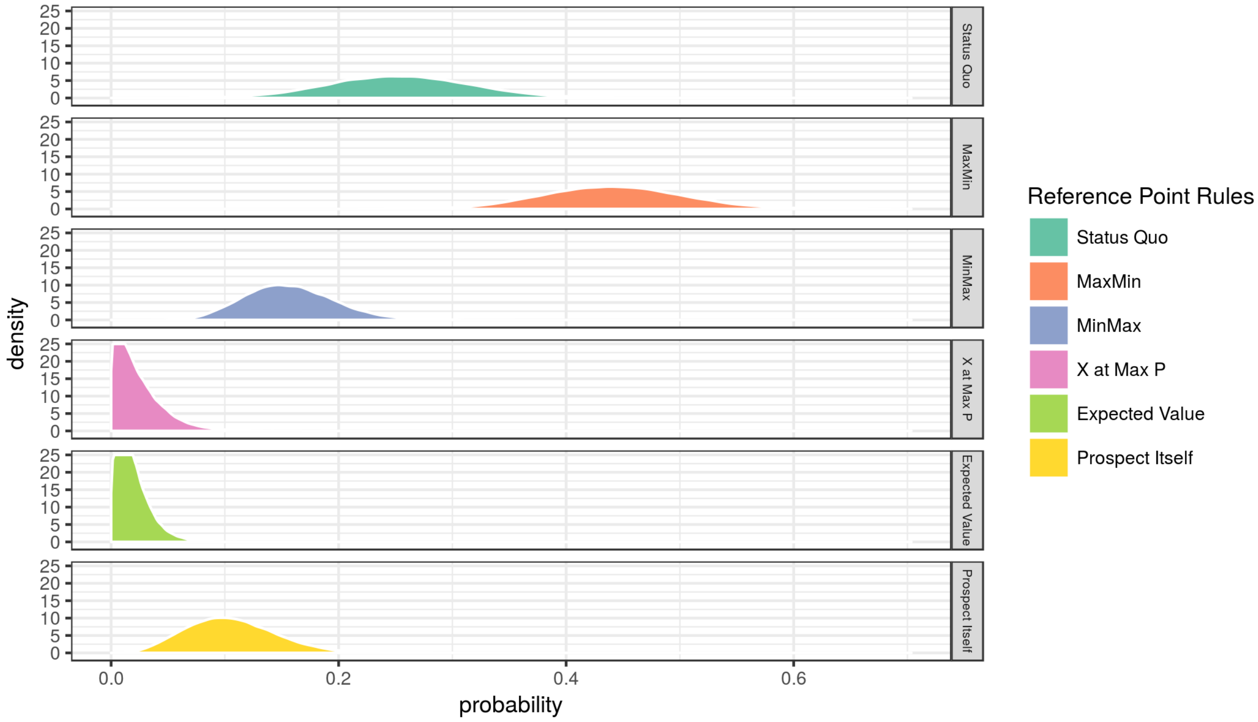


Figure 23: Posterior densities for RP rules in population

	Median	SD
Status Quo	0.25	0.06
MaxMin	0.44	0.06
MinMax	0.15	0.04
X at Max P	0.02	0.02
Expected Value	0.02	0.01
Prospect Itself	0.10	0.04

Table 30: Point estimates of RP mixture in population.

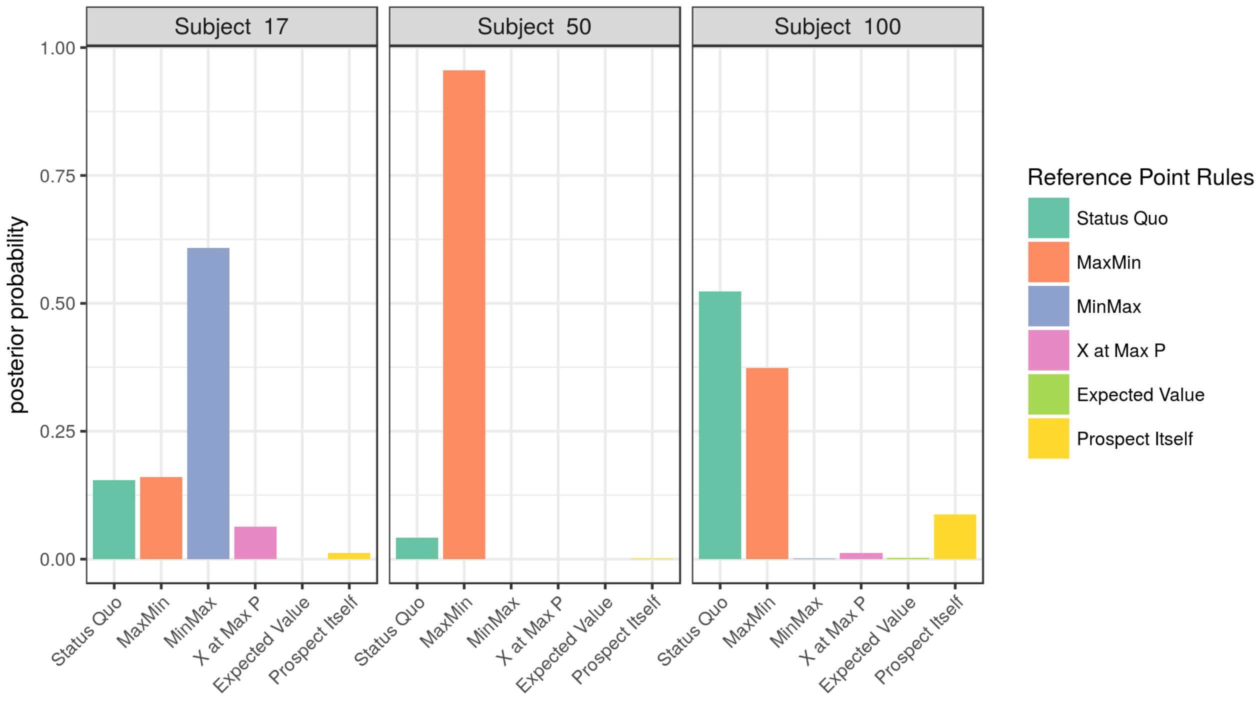


Figure 24: Posterior probability of a selection of subjects using a particular model

	Nr
Status Quo	29
MaxMin	61
MinMax	17
X at Max P	0
Expected Value	1
Prospect Itself	9

Table 31: Sharp predictions. Number of subjects for which the posterior probability of the respective reference point is higher than 0.5.

	α	γ	λ	ξ	Nr
MinMax	0.45	0.09	0.66	10.86	17
Status Quo	0.47	0.20	1.50	10.36	29
MaxMin	0.49	0.11	2.12	10.12	61
Prospect Itself	0.46	0.25	2.06	10.21	9
Expected Value	0.52	0.15	2.21	9.72	1
other	0.51	0.20	1.46	7.26	22
ALL	0.48	0.15	1.56	10.11	139

Table 32: Median individual level parameters for each sharply clasified group.

8 Model 4

8.1 Behavioral Parameters

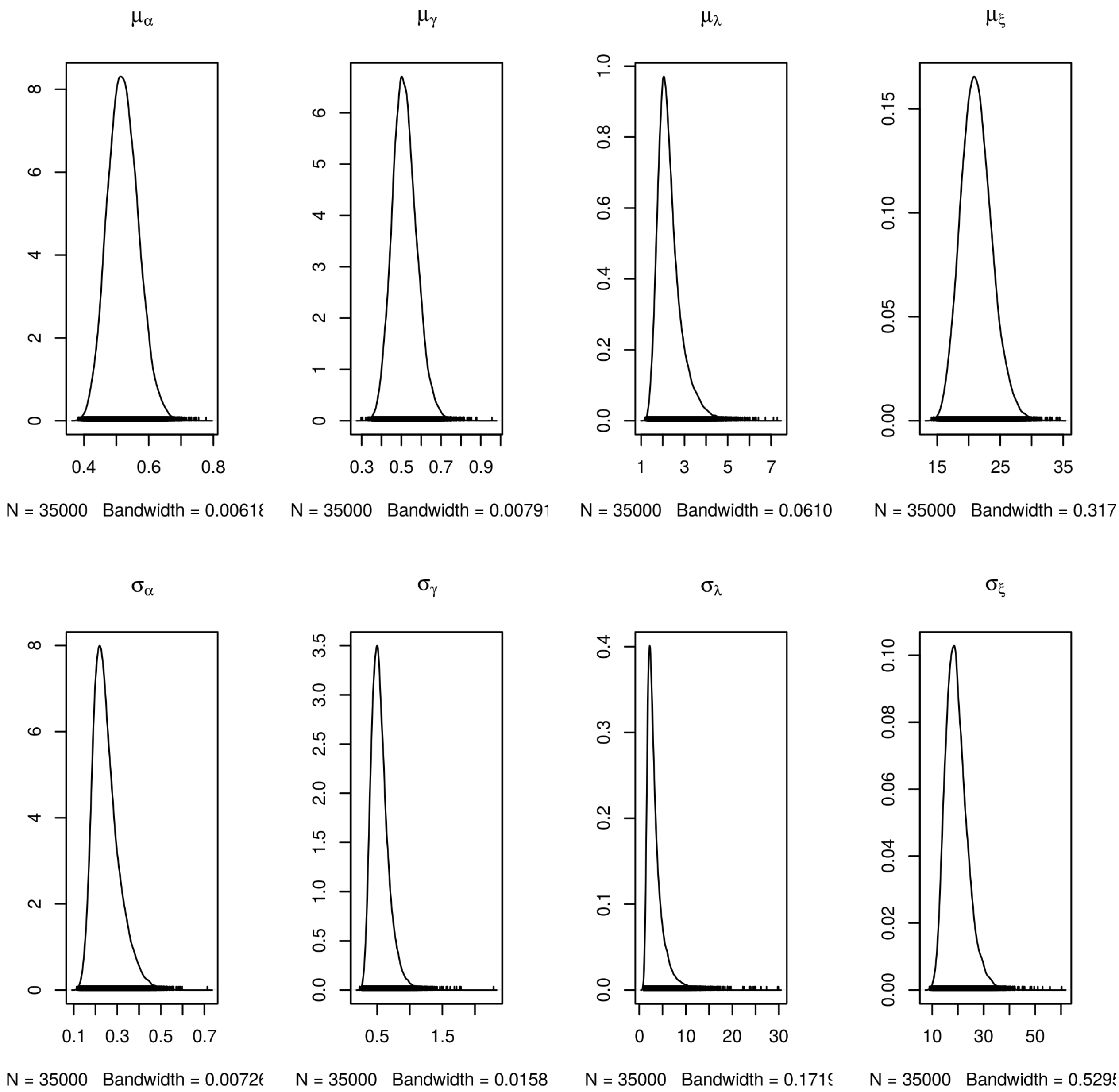


Figure 25: Posterior densities of behavioral parameters in population.

	μ	σ
α	0.52	0.24
γ	0.51	0.52
λ	2.19	2.81
ξ	21.12	18.97

Table 33: Posterior point estimates of behavioral parameters in population: α - exponent of power utility, γ - parameter of Prelec weighting function, λ - loss aversion.

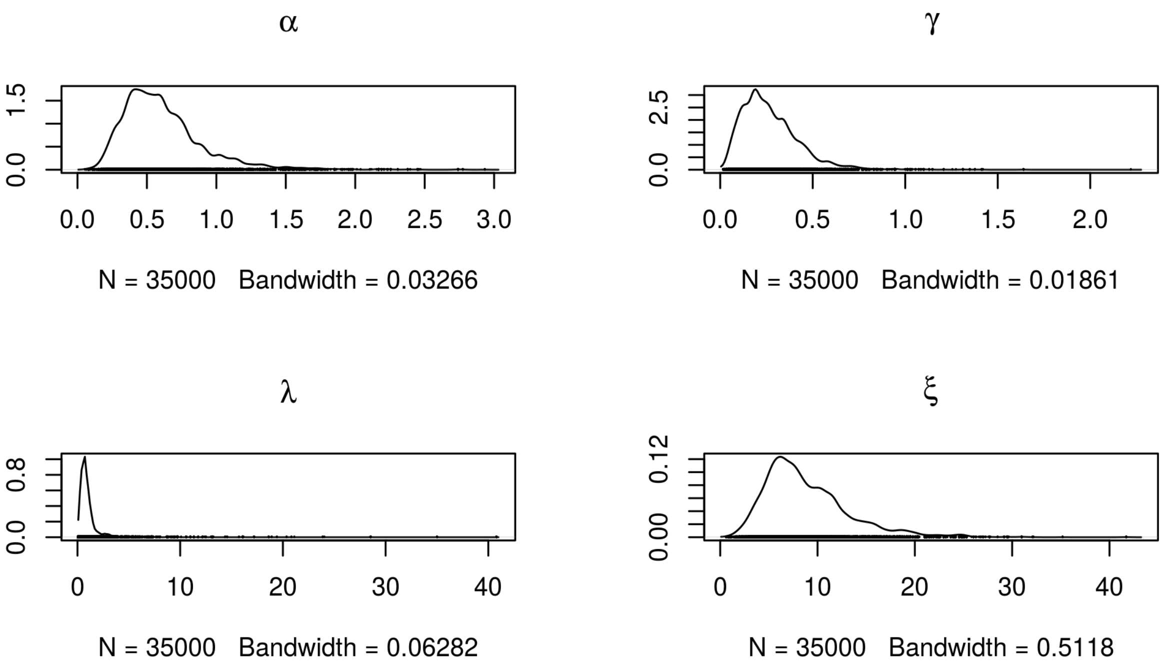


Figure 26: Posterior densities of behavioral parameters for subject 17 (B_{17})

	Median	SD
α	0.56	0.30
γ	0.24	0.16
λ	0.76	1.57
ξ	7.87	4.35

Table 34: Posterior summaries for subject 17.

8.2 Reference Points

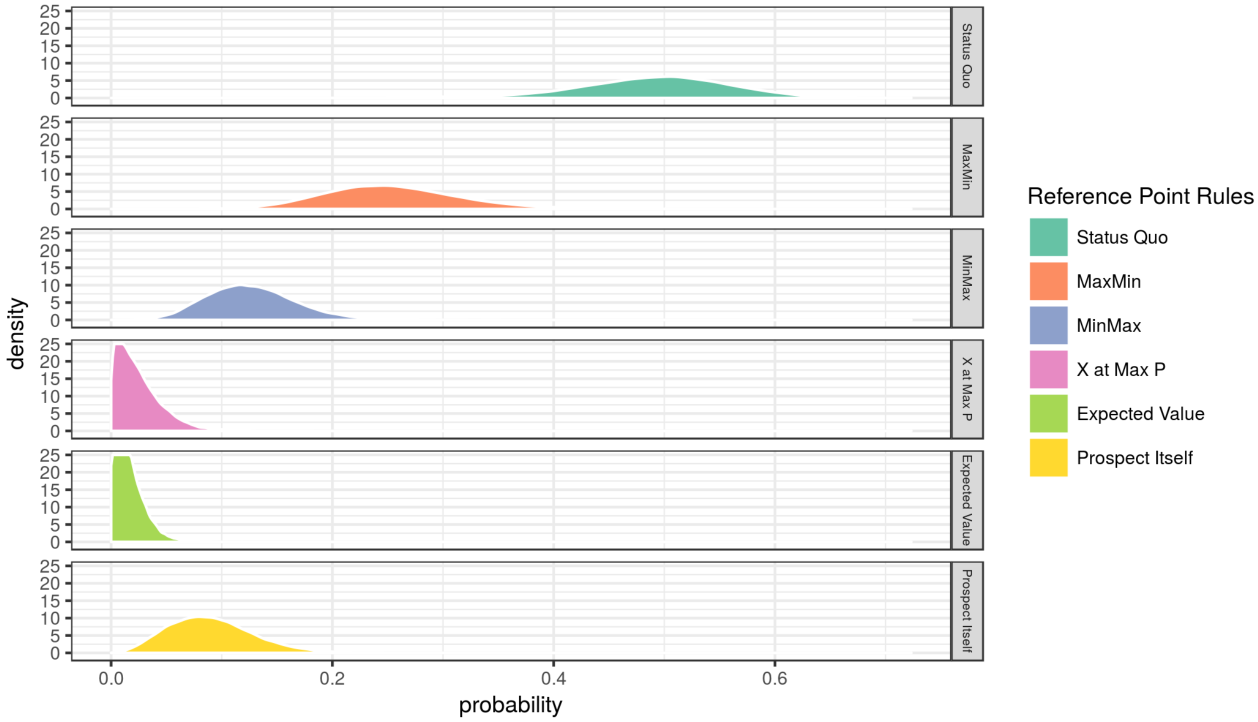


Figure 27: Posterior densities for RP rules in population

	Median	SD
Status Quo	0.49	0.07
MaxMin	0.25	0.06
MinMax	0.12	0.04
X at Max P	0.02	0.02
Expected Value	0.01	0.01
Prospect Itself	0.09	0.04

Table 35: Point estimates of RP mixture in population.

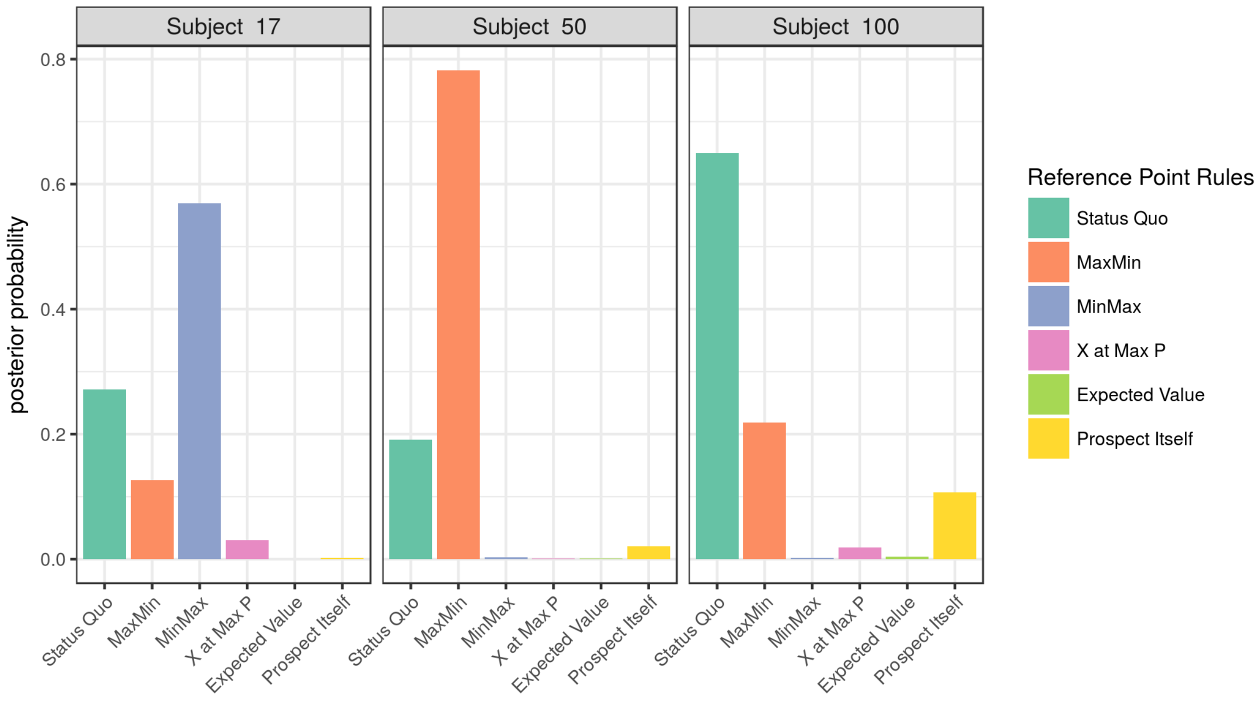


Figure 28: Posterior probability of a selection of subjects using a particular model

	Nr
Status Quo	74
MaxMin	26
MinMax	12
X at Max P	0
Expected Value	1
Prospect Itself	6

Table 36: Sharp predictions. Number of subjects for which the posterior probability of the respective reference point is higher than 0.5.

	α	γ	λ	ξ	Nr
Status Quo	0.45	0.42	1.43	19.52	74
Prospect Itself	0.43	0.47	1.90	13.18	6
MinMax	0.54	0.25	0.56	17.31	12
MaxMin	0.49	0.30	2.29	14.28	26
Expected Value	0.51	0.39	2.00	12.61	1
other	0.56	0.59	0.94	11.58	20
ALL	0.48	0.39	1.44	15.37	139

Table 37: Median individual level parameters for each sharply clasified group.

9 Instructions (translated from Romanian)

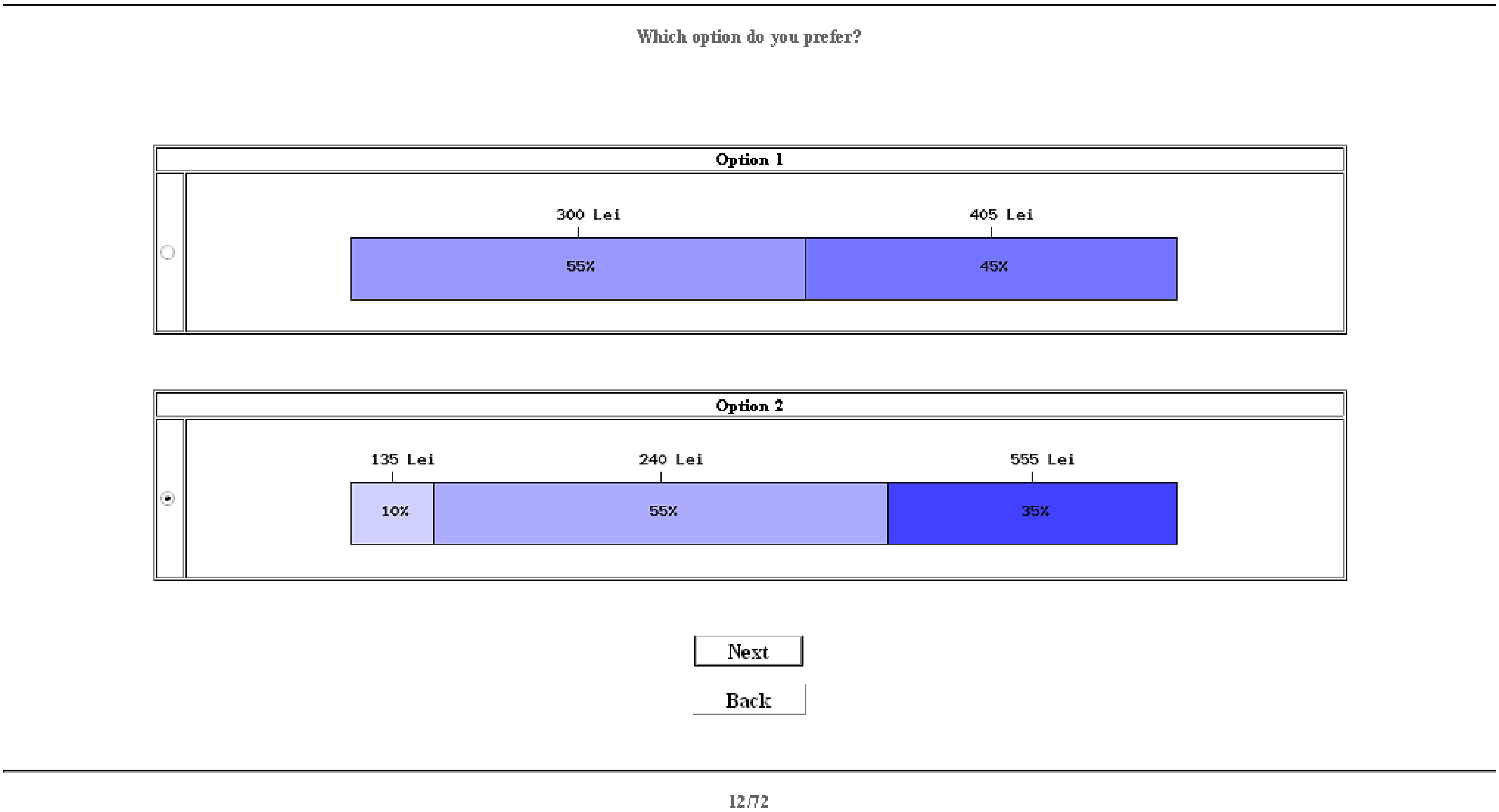
9.1 Screen 1 (log in)

Welcome to the Taking Decisions under Risk experiment.

Please log in with your ID and read carefully the instructions that follow.

9.2 Screen 2 (Questions)

The experiment consists of 70 questions. Each question consists of two risky options. A typical question is presented below.



In this example, the first option offers a gain of 300 Lei with probability of 55%, and a gain of 405 Lei with probability of 45%. The second option offers the gains 135 Lei, 240 Lei and 555 Lei with the corresponding probabilities 10%, 55% and 35%.

The width of colored segments is proportional to the corresponding events probability. The intensity of the color of each segment is proportional to corresponding events gain.

For each question, you will be asked to choose the option you preferred by clicking on the radio button displayed at the left-hand side of the option. In the above example, the second option was chosen.

At the end of the experiment, one of your choices may be played for real (the details of the payment mechanism are given on the next slide).

9.3 Screen 3 (Payment)

Each participant of the experiment will be given a fixed participation fee of 50 Lei.

Each participant will be given a one in three (1/3) chance of one of his/her options to be played for real. The 1/3 chance is determined by a selection of a green ball out of 3 balls (1 green + 2 white) from a closed urn.

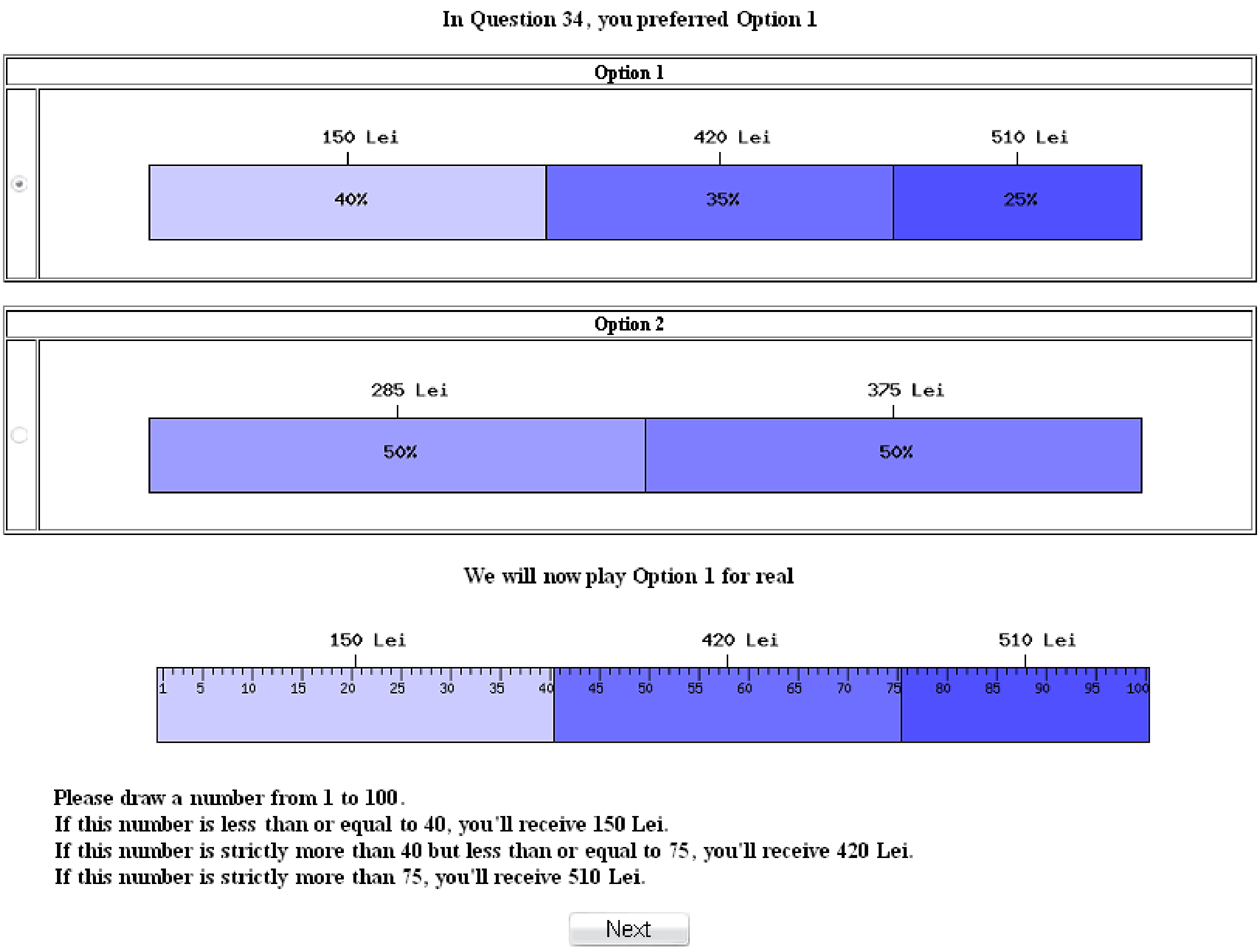
If the participant extracted the green ball, a number from 1 to 70 will be extracted randomly and the lottery chosen by the participant at that question will be played for real (the procedure of random extraction of the number between 1 and 70 will be explained below).

Next a number from 1 to 100 is extracted by the participant. This number will determine uniquely the participants outcome. The following example illustrates the correspondence between the random number in 1-100 and the value of the gain.

A hypothetical example:

Suppose the participant (Sanda) extracted the green ball and is now eligible for the random payment.

Now, suppose the extracted question is Question 34 (see the attached image), and the two digit number extracted by Sanda is 82, as the picture below indicates. During the experiment, Sanda chose Option 1 for this question. The gain corresponding to Option 1 and random number 82 is 510 Lei.



Obviously, this procedure generates outcomes with the same probabilities as indicated in the chosen option. The larger the number extracted, the bigger the gain.

Random Number Extraction Procedure

The extraction procedure for question numbers from 1 to 70 and winning number from 1 to 100 follows similar rules. Let us take the second case for illustration.

Firstly, the participant is asked to extract two balls: one from each of two separate urns. The first urn contains balls with numbers ranging from 0 to 9 and represents tens in a two digit number. The second urn contains balls with numbers from 1 to 10 and represents units in a two digit number. The final number is computed with the formula N1*10+N2. For example if N1 is 3 and N1 Is 2 then the corresponding two digit number is 32, if the numbers are 0 and 9 then the final number is 9; if the numbers are 7 and 10 then the two digit number is 80. By the above procedure, any number from 1 to 100 can be extracted randomly and uniformly.

The same mechanism is used for questions number extraction. The only difference is that the first urn contains only numbers ranging from 0 to 6.

9.4 Screen 4)

[Start Button]

Good Luck!

10 Derivation that Abeler et al.'s (2011) results are consistent with the MaxMin rule

In the experiment of Abeler et al. (2011), the subject could perform a task many times and received either a fixed payment f with probability 50% or we with probability 50% where e is the effort (the number of tasks performed) and $w > 0$ the piece rate per task. There were two treatments defined by the value of f: the low treatment (LO) and the high treatment (HI), with $f_{LO} < f_{HI}$. In a model without a reference point or with the reference point equal to the status quo, the subjects should perform the same number of tasks in both treatments. Abeler et al. (2011) derived two hypotheses when the prospect itself is the reference point (the rule suggested by Kszegi and Rabin's (2007) CPE model):

- Hypothesis 1: Average effort in the HI treatment is higher than in the LO treatment.
- Hypothesis 2: The probability to stop at $we = f_{LO}$ is higher in the LO treatment than in the HI treatment; the probability to stop at $we = f_{HI}$ is higher in the HI treatment than in the LO treatment.

The results of their experiment were in line with these hypotheses. We will now show that we can derive the same hypotheses with the MaxMin rule. First, subjects' choice sets consisted of binary prospects $(50\%, f; 50\%, we)$ for all e. The minimum outcome is we if $we < f$ and f otherwise. Hence the maximum of the minimum outcomes is f and the MaxMin rule predicts f to be the reference point. We adopt now the same model as Abeler et al. (2011) but with the MaxMin rule. They consider a piecewise linear gain-loss utility with $U(x) = \eta x$ for gains and $U(x) = \eta\lambda x$ for losses with $\eta \geq 0$ and $\lambda > 1$. The cost of performing effort e is $c(e)$.

If $we < f$ the subjects will maximize:

$$\frac{we + f}{2} - c(e) + \frac{1}{2}\eta\lambda(we - f) \tag{1}$$

If $we \geq f$ they will maximize:

$$\frac{we + f}{2} - c(e) + \frac{1}{2}\eta(we - f) \tag{2}$$

The first-order conditions (FOCs) give:
if $we < f$:

$$c'(e^*) = \frac{1}{2}w(1 + \eta\lambda) \tag{3}$$

if $we \geq f$:

$$c'(e^*) = \frac{1}{2}w(1 + \eta) \tag{4}$$

Hence, the marginal utility of providing an effort (the second member of the FOC equations) is higher when accumulated earnings we are below the reference point f than when they exceed it, because of the loss aversion coefficient ($\lambda > 1$). Increasing the fixed payment from f_{LO} to f_{HI} increases the marginal utility of providing an effort when the accumulated earnings are within this range. Hence, Hypothesis 1 follows. To show that MaxMin also predicts the second hypothesis, there is a discrete drop of the marginal utility of efforts when $we = f$, which will cause some subjects to stop their effort at precisely this level, in line with Hypothesis 2.