Halfway Report 23-01-04

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Initial data checks

One participant had fewer than 630 total trials (total of 455 trials remained in file) and was missing columns for the final 3 MCQ questions (4-6). However, this participant was still included in analysis.

Four participants were excluded for not passing the requirement for MCQ questions, post-game quiz or questions after betting in yellow (I want to remember the odds guess questions are). Three excluded participants were in control treatment and one in the test treatment.

All excluded participants were cravers, as defined by betting at least twice in yellow.

Main analysis

This section goes through the tests specified in the pre-registration report and specifies observed effect sizes in the sample so far.

There was a total of 113 participants after excluding participants.

Test 1

Paired one-tailed t-test checking if betting rate is equal or lower in high reward value trials. Participant-level test (N = 113).

Data was skewed at 1.69 (ideal values within [-1, 1]) and a Shapiro-Wilks test showed non-normality. Data were Box-Cox transformed with lambda = -19. This reduced skew to 0.909 (acceptable value), but SW test still showed non-normality.

Paired t-test using Box-Cox transformed data showed higher betting rate in high reward sessions ($t(112) = -5.238$, $p < .001$). Non-parametric paired Wilcoxon test using non-transformed data showed qualitatively same results ($V = 84.5$ $p < .001$).

Test 2

Logistic mixed-effects model predicting betting in all trials. Using penalized log-likelihood to correct for imbalanced groups.

	Beta	SE	z-value	p-value
(Intercept)	-5.253	0.393	-13.368	< .001 ***
reward_valueHigh	1.374	0.057	23.918	< .001 ***
uncertaintyHigh	0.259	0.051	5.121	< .001 ***
treatmentTest	1.041	0.311	3.349	0.001 **
colorBlue	10.811	0.190	56.754	< .001 ***
age	-0.076	0.156	-0.489	0.625
gender2	-0.174	0.310	-0.563	0.574
gender3	-0.661	1.448	-0.457	0.648
major2	0.438	0.337	1.299	0.194
major3	0.176	1.078	0.163	0.871
major4	1.906	1.088	1.751	0.08
treatmentTest:colorBlue	-3.107	0.206	-15.096	< .001 ***

Test 3

Mixed-effects model predicting betting in all trials. Same as test 2, but with exposure time added in order to see if betting increases with reward exposure.

	Beta	SE	z-value	p-value
(Intercept)	-5.171	0.390	-13.247	< .001 ***
reward_valueHigh	1.373	0.057	23.911	< .001 ***
uncertaintyHigh	0.262	0.051	5.179	< .001 ***
treatmentTest	0.962	0.312	3.081	0.002 **
colorBlue	10.695	0.201	53.266	< .001 ***
age	-0.070	0.156	-0.447	0.655
gender2	-0.169	0.307	-0.551	0.582
gender3	-0.583	1.432	-0.407	0.684
major2	0.447	0.334	1.337	0.181
major3	0.175	1.067	0.164	0.87
major4	1.890	1.079	1.752	0.08
reward_history	0.060	0.035	1.715	0.086
treatmentTest:colorBlue	-2.998	0.215	-13.974	< .001 ***

In addition to the regression table, the reward history variable can be tested by comparing the model from test 2 with this one to see if the addition of reward history statistically significantly improved fit.

Comparing the models, the difference between them is not statistically significant (Chi2(1) = 2.542, p = 0.111). The models had similar AIC (test2 = 1.2525×10^4, test3 = 1.2524×10^4) and the model from test 2 had lower BIC than the model from test 3 (1.2643×10^4 compared to 1.2652×10^4). This means the model in test 2 is preferred due to having fewer variables while explaining the data equally well.

Test 3.1

This test is a copy of test 2, but with previous choice added as a variable instead of reward history. The same method is used to check the models.

	Beta	SE	z-value	p-value
(Intercept)	-5.485	0.345	-15.913	< .001 ***
reward_valueHigh	1.234	0.059	20.994	< .001 ***
uncertaintyHigh	0.218	0.052	4.163	< .001 ***
treatmentTest	0.798	0.276	2.891	0.004 **
colorBlue	9.512	0.189	50.244	< .001 ***
age	-0.060	0.138	-0.433	0.665
gender2	-0.129	0.272	-0.474	0.636
gender3	-0.475	1.291	-0.368	0.713
major2	0.400	0.296	1.353	0.176
major3	0.157	0.959	0.163	0.87
major4	1.648	0.968	1.703	0.089
previous_choice	1.605	0.057	28.218	< .001 ***
treatmentTest:colorBlue	-2.722	0.202	-13.455	< .001 ***

In addition to the regression table, the exposure variable can be tested by comparing the model from test 2 with this one to see if the addition of reward exposure statistically significantly improved fit.

Comparing the models, the difference between them is statistically significant (Chi2(1) = 2.542, p = 0.111). The model with previous choice had lower AIC (test2 = 1.2525×10^4, test3 = 1.2524×10^4) and lower BIC (1.2643×10^4 compared to 1.2652×10^4). This means the model with previous choice is preferred.

Test 4

Test 5

Logistic mixed-effects model predicting betting among cravers in the yellow background sessions.

	Beta	SE	z-value	p-value
(Intercept)	-3.718	0.398	-9.334	< .001 ***
reward_valueHigh	1.320	0.094	14.055	< .001 ***
uncertaintyHigh	0.726	0.088	8.242	< .001 ***
treatmentTest	0.380	0.322	1.180	0.238
previous_choice	1.324	0.089	14.954	< .001 ***
age	-0.243	0.185	-1.314	0.189
gender2	-0.165	0.322	-0.512	0.609
major2	0.074	0.407	0.181	0.856
major4	1.464	0.950	1.541	0.123

Test 6

Bayesian t-test checking if betting rate in yellow session in the test treatment is different from 0. Participant-level test (N = 57).

Data was positively skewed at 1.016 (ideal values within [-1, 1]) and a Shapiro-Wilks test showed non-normality. Data were Box-Cox transformed with lambda = -4.75. This reduced skew to 0.565 (acceptable value), but SW test still showed non-normality.

Bayesian t-test on Box-Cox transformed betting rate showed a Bayes Factor of 4.398, with a probability of 81.5% that the mean was more than 0.

Test 7

Paired one-tailed t-test checking if betting rate is equal or lower in high uncertainty trials. Participant-level test.

Data was positively skewed at 0.818 (ideal values within [-1, 1]) and a Shapiro-Wilks test showed non-normality. Data were Box-Cox transformed with lambda = -8.75. This reduced skew to 0.818 (acceptable value), but SW test still showed non-normality.

Paired t-test using Box-Cox transformed data showed higher betting rate in high uncertainty sessions ($t(112) = -2.758$, $p = 0.003$). Non-parametric paired Wilcoxon test on non-transformed data showed qualitatively same results ($V = 232.5$ $p < .001$).

Plots

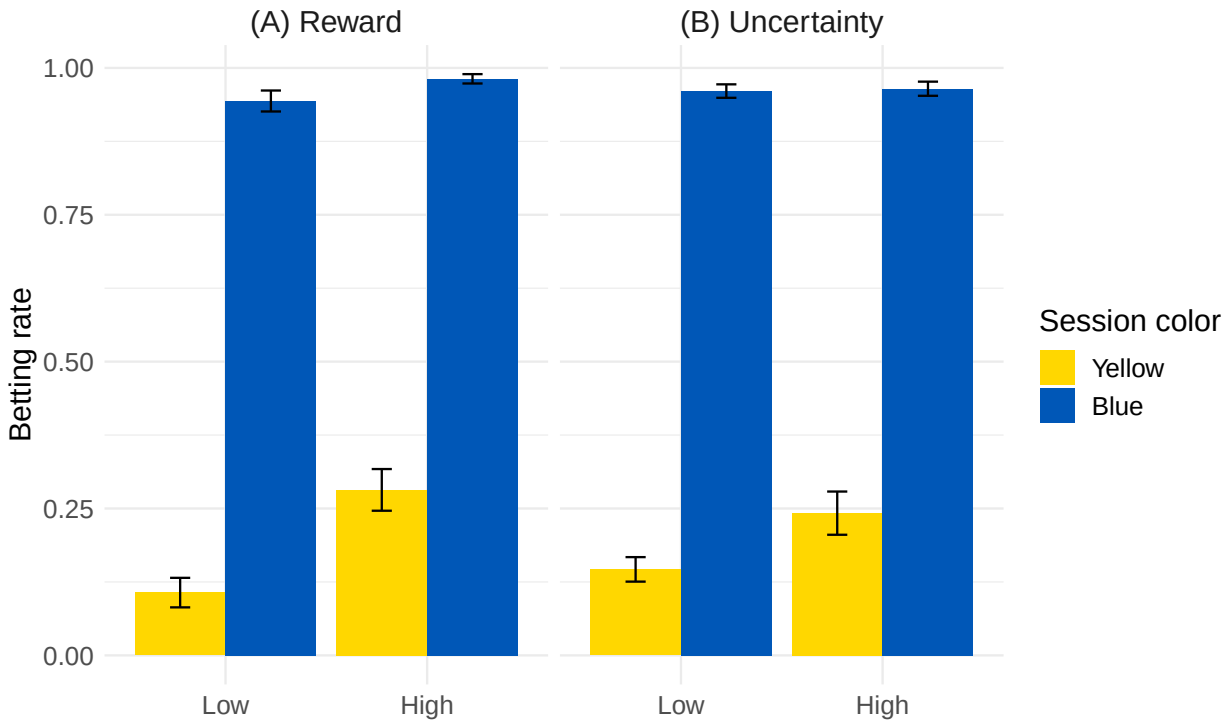

Figure 1: (A) Average betting rate in low and high reward sessions. (B) Average betting rate in low and high uncertainty sessions.

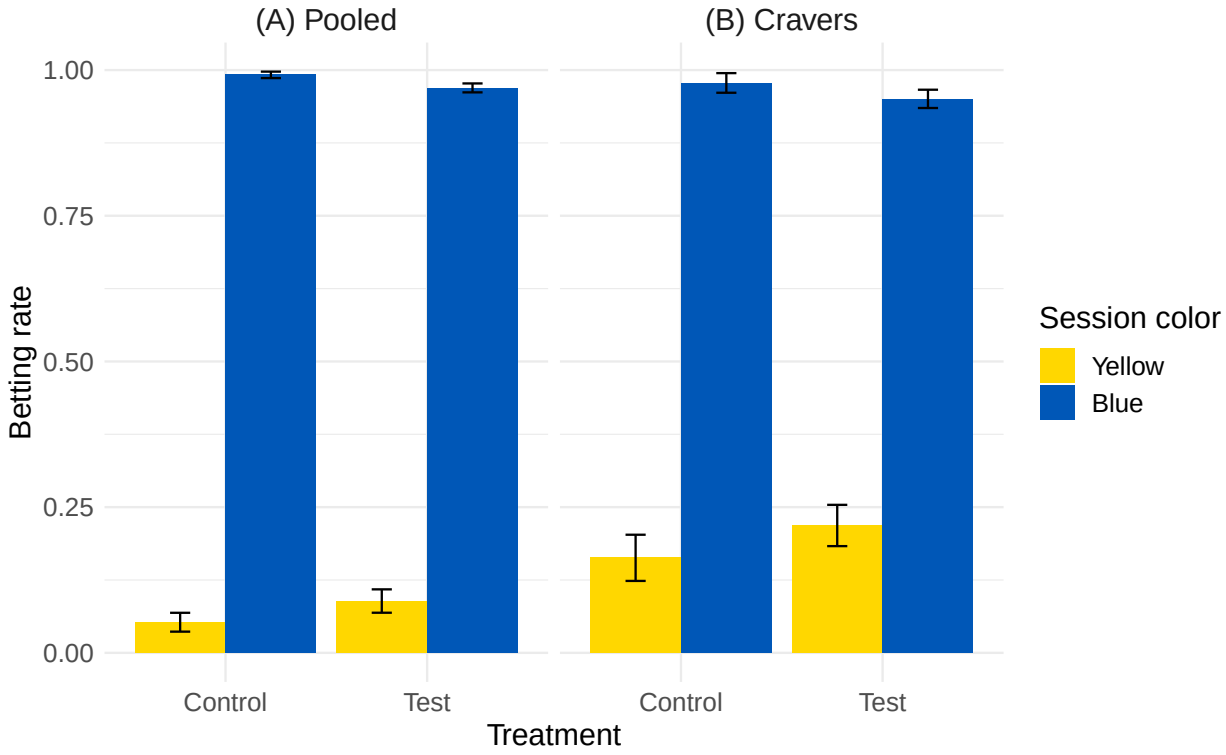

Figure 2: Average betting rate by session color and treatment, for all participants pooled and cravers individually.

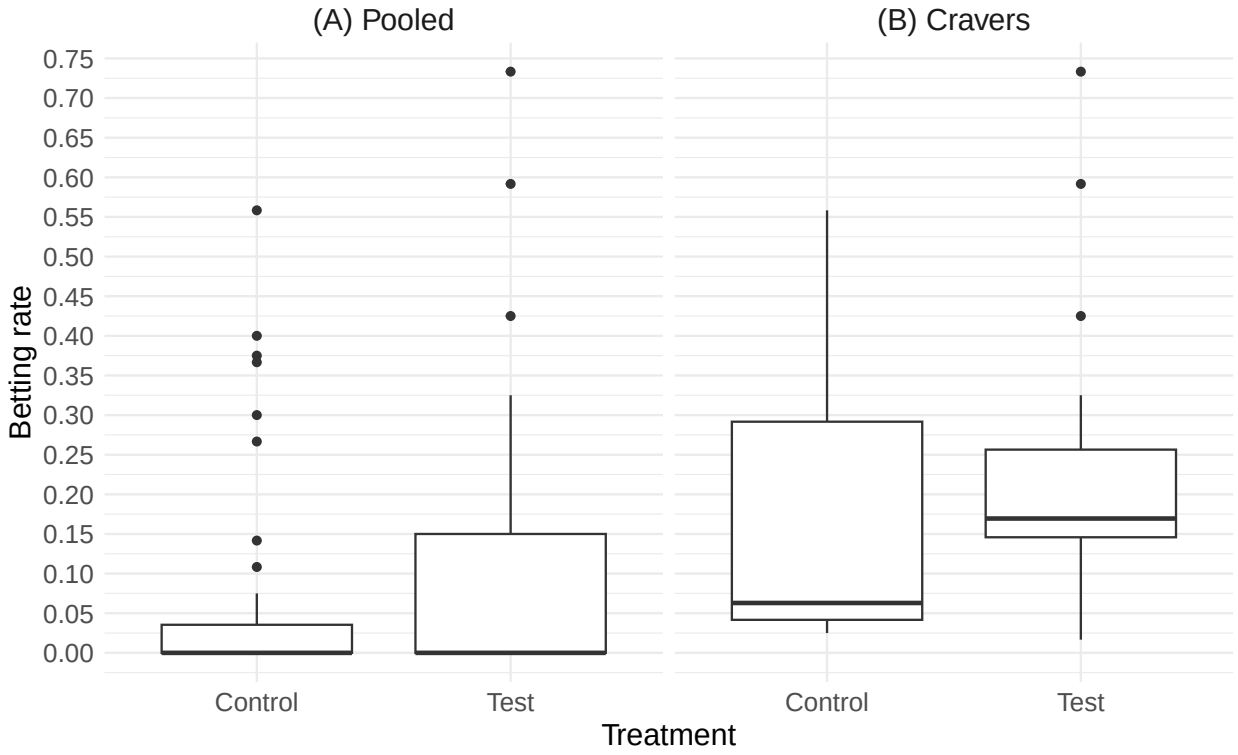

Figure 3: Distribution of betting rates by participant for all participants (A) and for the craver group (B) in yellow background sessions.

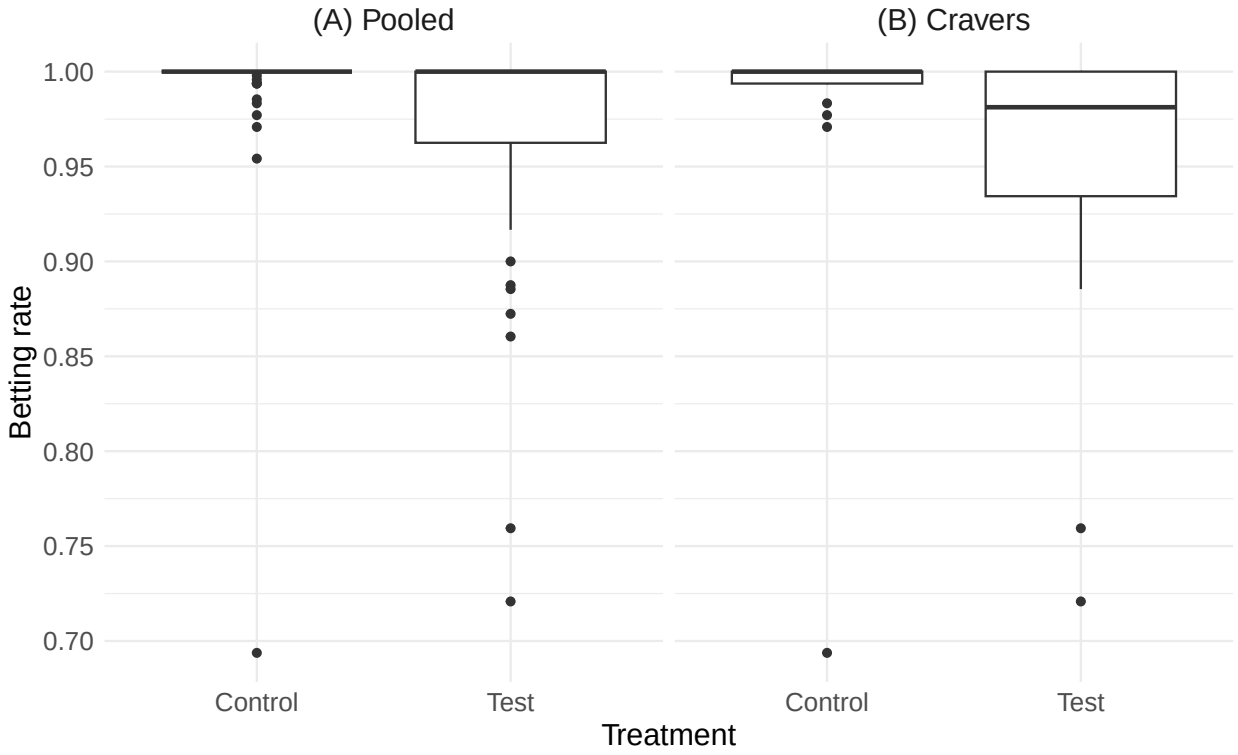

Figure 4: Distribution of betting rates by participant for all participants (A) and for the craver group (B) in blue background sessions.

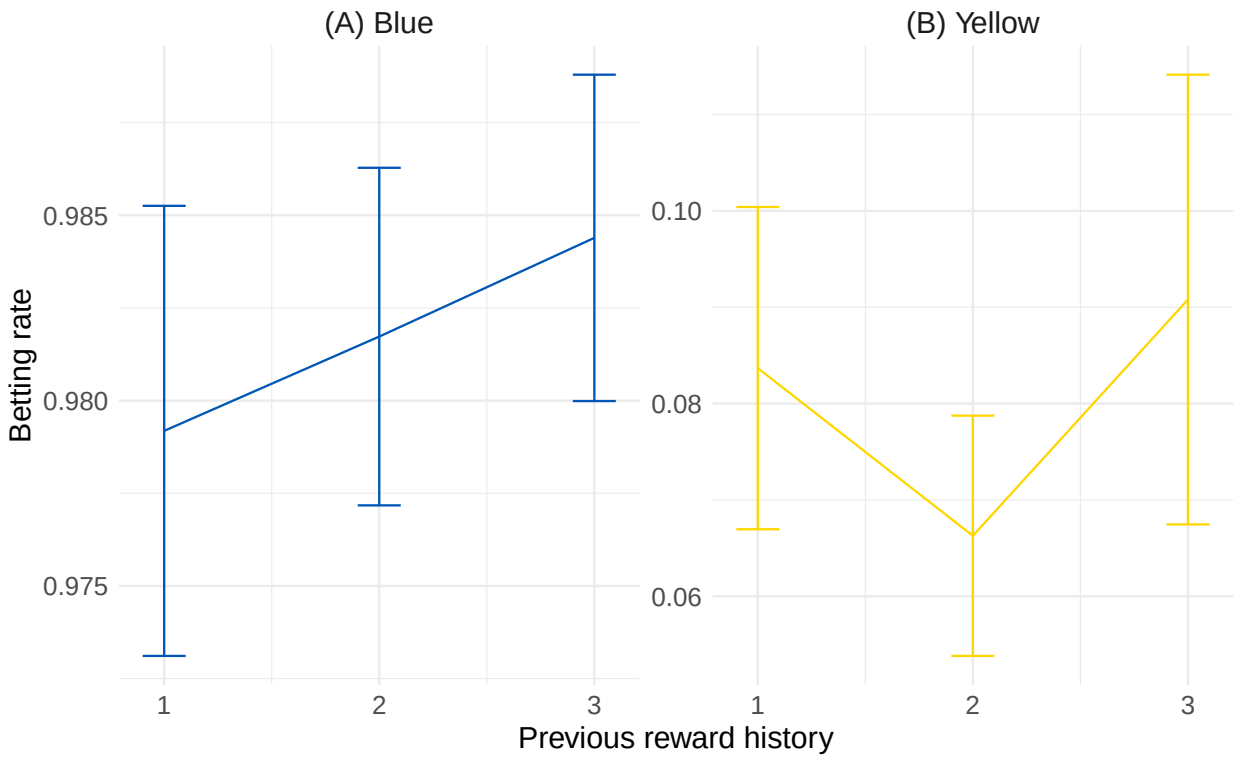

Figure 5: Betting rate in the blue background sessions (A) and yellow background sessions (B) as a function of prior reward history (as defined in computational model) for all participants and sessions, with reward history split into 3 equally sized bins.

Extra treatment/uncertainty checks

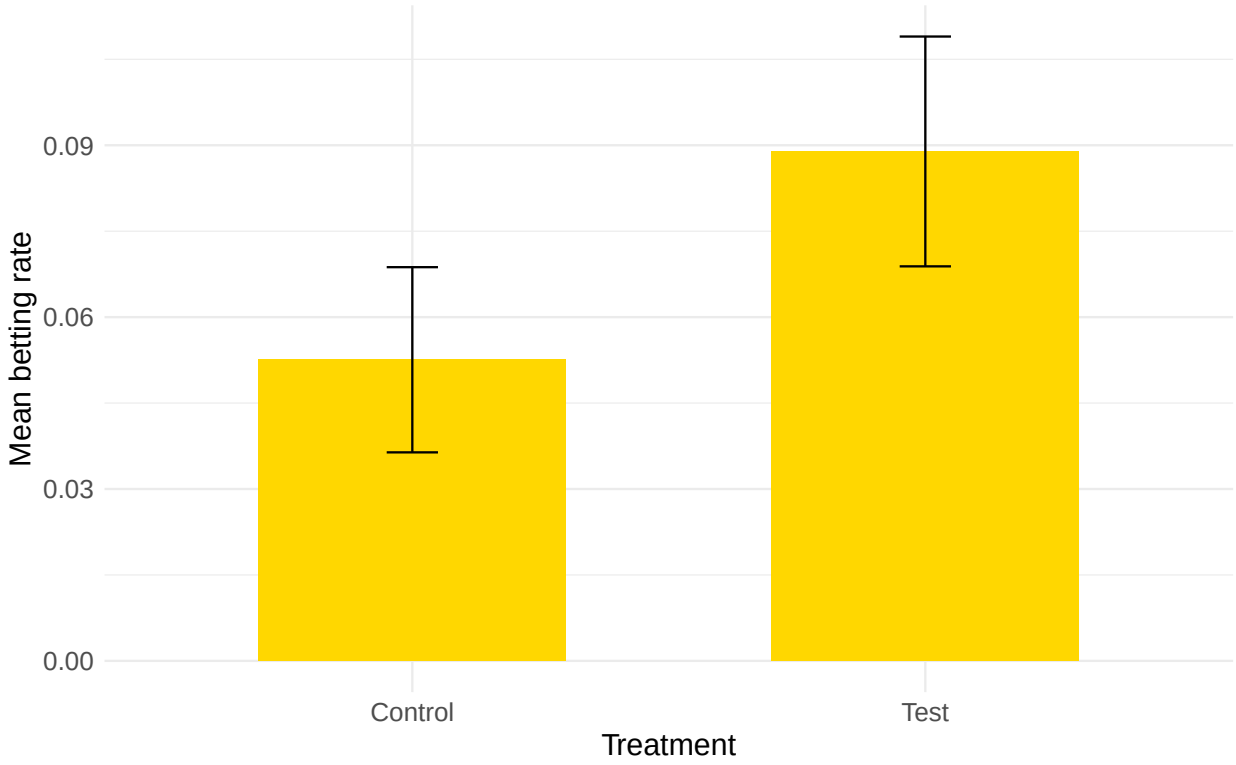

Figure 6: Average betting rate in yellow sessions for the control and test treatment.

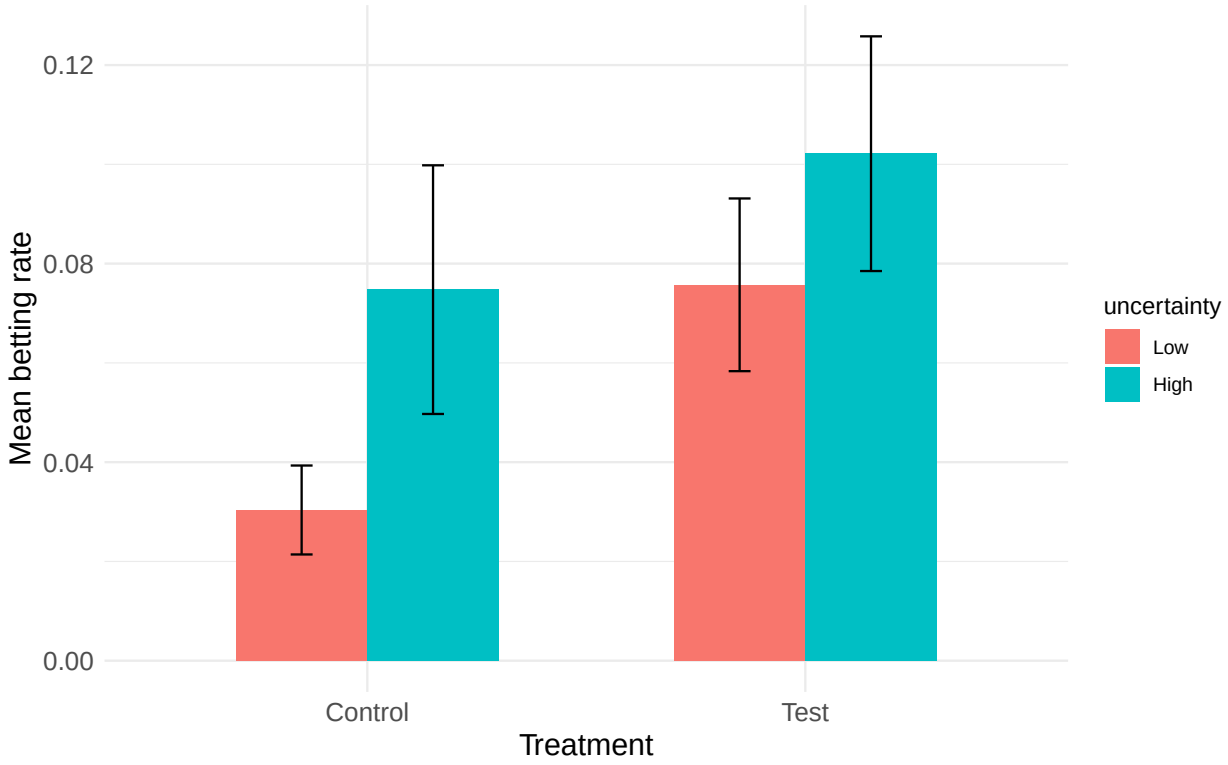

Figure 7: Average betting rates in control/test treatment for low/high uncertainty. There seems to be an effect of uncertainty in the control treatment but not in test.

Reaction time stuff

The effect of reaction time was checked using 3 tests. First, the logistic models from test 2 and test 5 were built but with the added value for reaction time. Then a plot was made showing reaction time by treatment and session color.

Test 2 copy

Logistic mixed-effects model predicting betting in all trials. Using penalized log-likelihood to correct for imbalanced groups.

	Beta	SE	z-value	p-value
(Intercept)	-5.207	0.383	-13.580	< .001 ***
reward_valueHigh	1.370	0.057	23.857	< .001 ***
uncertaintyHigh	0.262	0.051	5.175	< .001 ***
treatmentTest	1.002	0.306	3.278	0.001 **
colorBlue	10.786	0.189	56.930	< .001 ***
age	-0.086	0.155	-0.554	0.579
gender2	-0.148	0.305	-0.487	0.626
gender3	-0.547	1.428	-0.383	0.702
major2	0.386	0.332	1.164	0.244
major3	0.088	1.063	0.083	0.934
major4	1.838	1.074	1.712	0.087
reaction_time	0.113	0.025	4.469	< .001 ***
treatmentTest:colorBlue	-3.082	0.205	-15.045	< .001 ***

Test 5 copy

Logistic mixed-effects model predicting betting among cravers in the yellow background sessions.

	Beta	SE	z-value	p-value
(Intercept)	-3.767	0.392	-9.607	< .001 ***
reward_valueHigh	1.343	0.096	14.041	< .001 ***
uncertaintyHigh	0.789	0.090	8.805	< .001 ***
treatmentTest	0.343	0.317	1.084	0.279
previous_choice	1.184	0.090	13.133	< .001 ***
age	-0.259	0.182	-1.425	0.154
gender2	-0.163	0.316	-0.514	0.607
major2	0.045	0.399	0.113	0.91
major4	1.356	0.919	1.476	0.14
reaction_time	0.444	0.045	9.861	< .001 ***

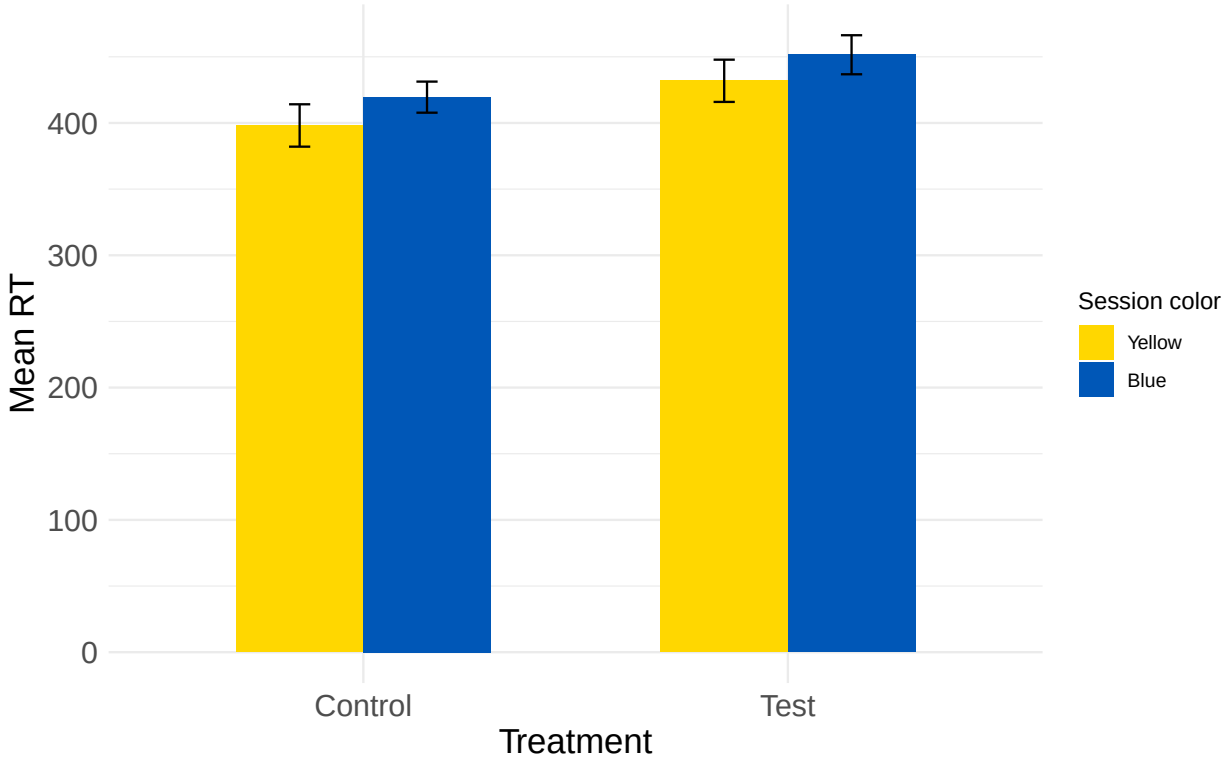

Figure 8: Average reaction time by session color and treatment.

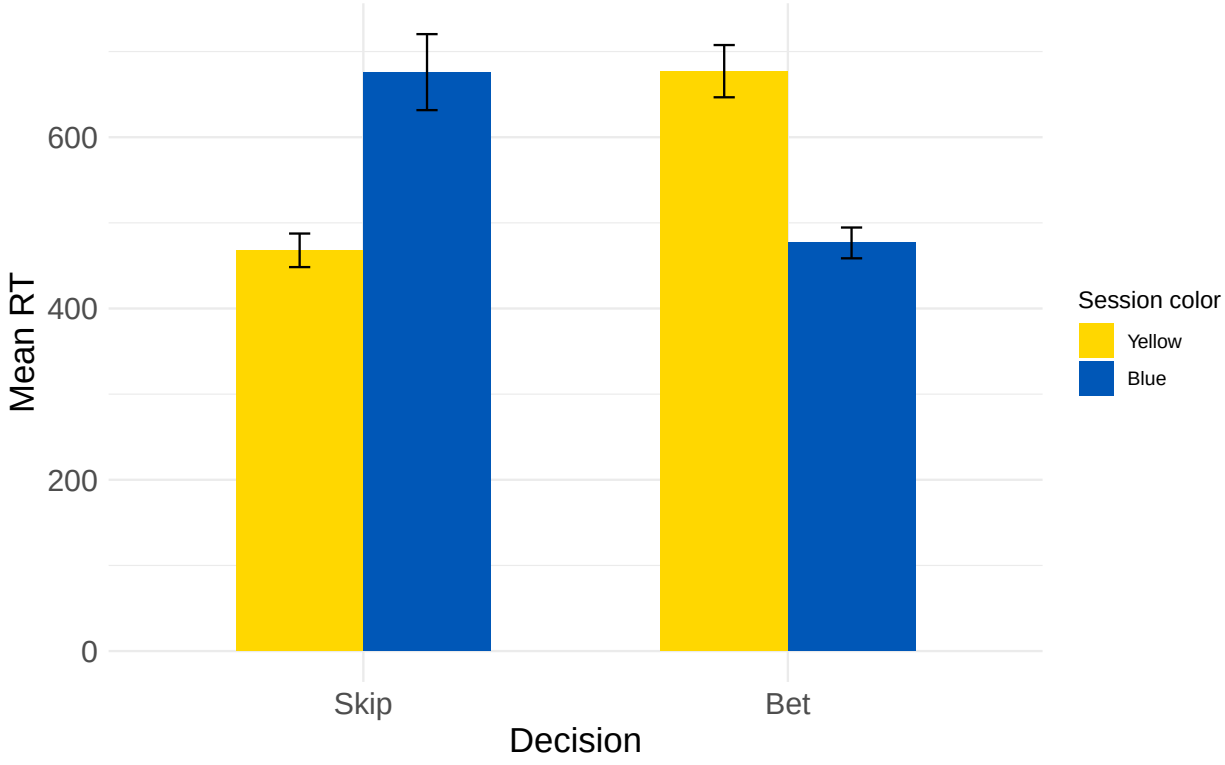

Figure 9: Average RT by decision (skip/bet) and session color (blue/yellow).

Treatment effect in new sample only

We also test the treatment effect in yellow in the new sample when we exclude all pilot participants. This subsample has 95 participants.

The treatment effect is examined by running test 5 and producing figure 2 for the new sample alone.

Test 5 copy

	Beta	SE	z-value	p-value
(Intercept)	-3.409	0.482	-7.077	$< .001$ ***
reward_valueHigh	1.299	0.101	12.874	$< .001$ ***
uncertaintyHigh	0.732	0.095	7.696	$< .001$ ***
treatmentTest	0.349	0.359	0.974	0.33
previous_choice	1.408	0.096	14.690	$< .001$ ***
age	-0.086	0.192	-0.448	0.654
gender2	-0.168	0.359	-0.467	0.641
major2	-0.209	0.456	-0.458	0.647
major4	1.335	0.981	1.360	0.174

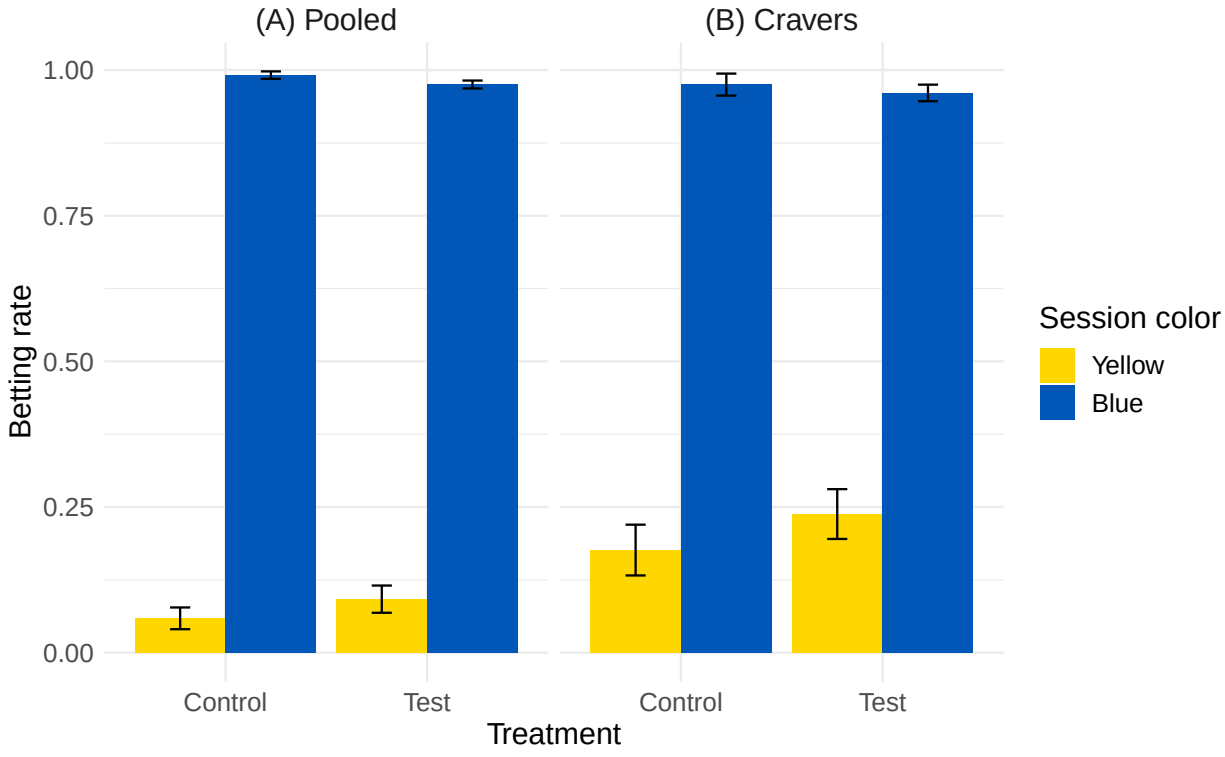

Figure 10: Bar chart showing betting rate in control and test treatment in yellow and blue background sessions. The panes represent data for all participants (A) and only cravers (B).

Reward history with different theta

This section checks results for the reward history variable when using theta = 0.95 instead of 0.9. This is done by reproducing test 3 and 5 as well as figure 5 using the new design of the reward history variable. In the copy of model 5, previous choice is removed as it correlates heavily with reward history.

Test 5 copy

	Beta	SE	z-value	p-value
(Intercept)	-3.501	0.463	-7.559	< .001 ***
reward_valueHigh	1.504	0.091	16.539	< .001 ***
uncertaintyHigh	0.820	0.085	9.608	< .001 ***
treatmentTest	0.669	0.403	1.658	0.097
age	-0.298	0.214	-1.392	0.164
gender2	-0.181	0.373	-0.486	0.627
major2	0.022	0.466	0.048	0.962
major4	1.494	1.047	1.427	0.154
reward_history	-0.067	0.093	-0.718	0.473

Test 3

Mixed-effects model predicting betting in all trials. Same as test 2, but with reward history added in order to see if betting increases with reward histoty

	Beta	SE	z-value	p-value
(Intercept)	-5.125	0.391	-13.096	< .001 ***
reward_valueHigh	1.368	0.057	23.835	< .001 ***
uncertaintyHigh	0.256	0.051	5.049	< .001 ***
treatmentTest	0.909	0.316	2.879	0.004 **
colorBlue	10.653	0.206	51.831	< .001 ***
age	-0.075	0.155	-0.487	0.626
gender2	-0.175	0.305	-0.575	0.566
gender3	-0.575	1.426	-0.403	0.687
major2	0.445	0.332	1.339	0.181
major3	0.127	1.064	0.120	0.905
major4	1.839	1.074	1.713	0.087
reward_history	0.073	0.040	1.820	0.069
treatmentTest:colorBlue	-2.938	0.223	-13.185	< .001 ***

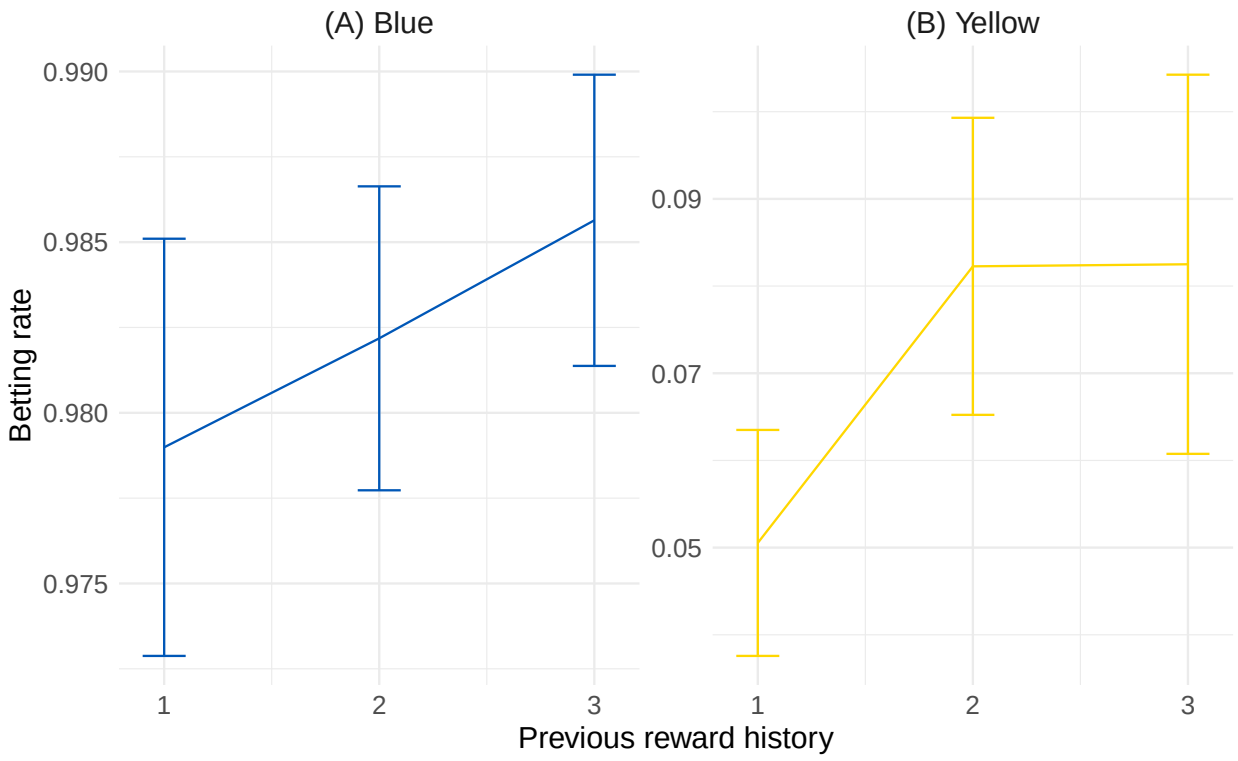

Figure 11: Betting rate in the blue background sessions (A) and yellow background sessions (B) as a function of prior reward history (as defined in computational model) for all participants and sessions, with reward history split into 3 equally sized bins.

Boredom in control in yellow

We wanted to check whether participants might bet in yellow in the control treatment out of boredom (skipping many times in a row could be boring as nothing happens). To do this, we fashioned a few extra variables and checked their importance in explaining differences in betting rates.

First, we produced two additional plots to check whether betting was different over the course of sessions in yellow in control. One variable compared the first session in a sequence of yellow to the second and third, and one variable compared the first and second session to the third in a sequence. The results are shown in the bar charts below.

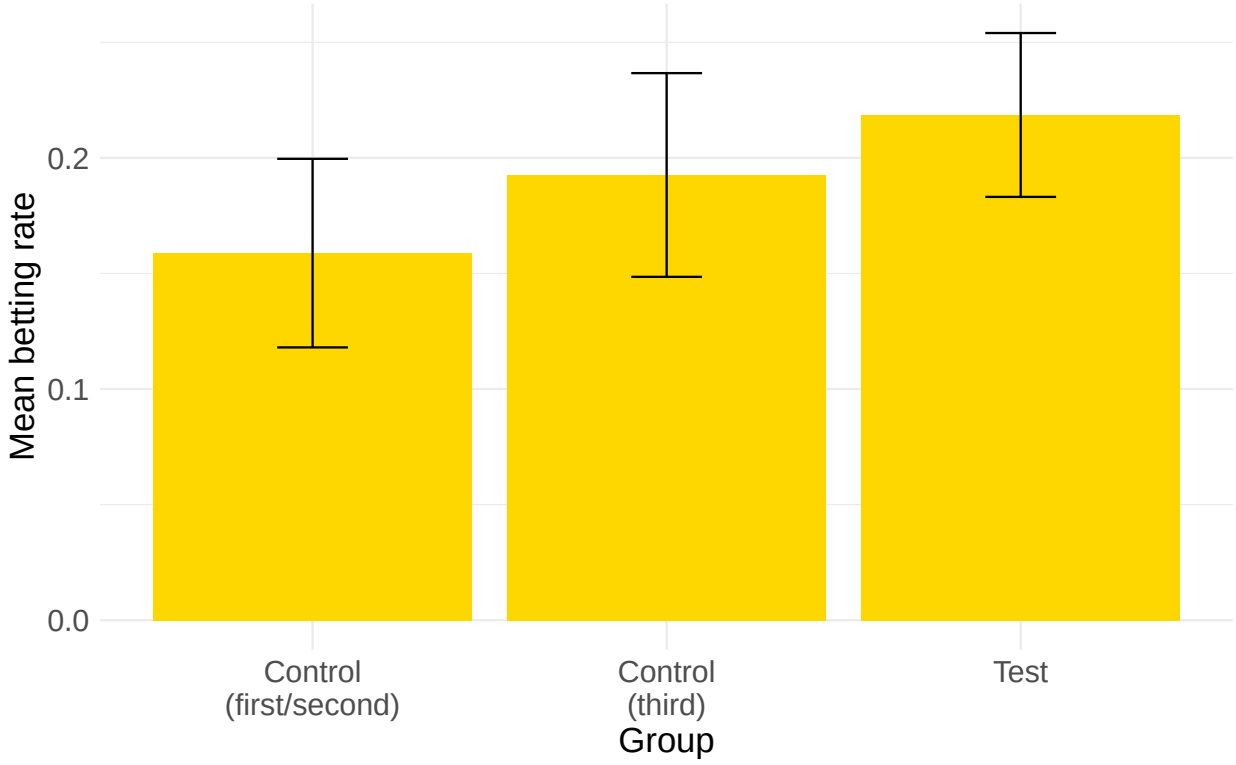

Figure 12: Betting rate in the first/second or third sessions in a sequence of yellow sessions in the control treatment. Betting rate for the test treatment is shown individually.

Next, a special version of test 5 in the main analysis above was run. We created two version of the same model. One restricting sessions in the control treatment to the first session in a sequence and one restricting sessions in control to the first/second sessions. This was done to avoid overcomplicating model architecture with additional variables and interactions. It also creates models with the assumption that all data is "free from boredom" rather than controlling for it. Regression tables are presented below.

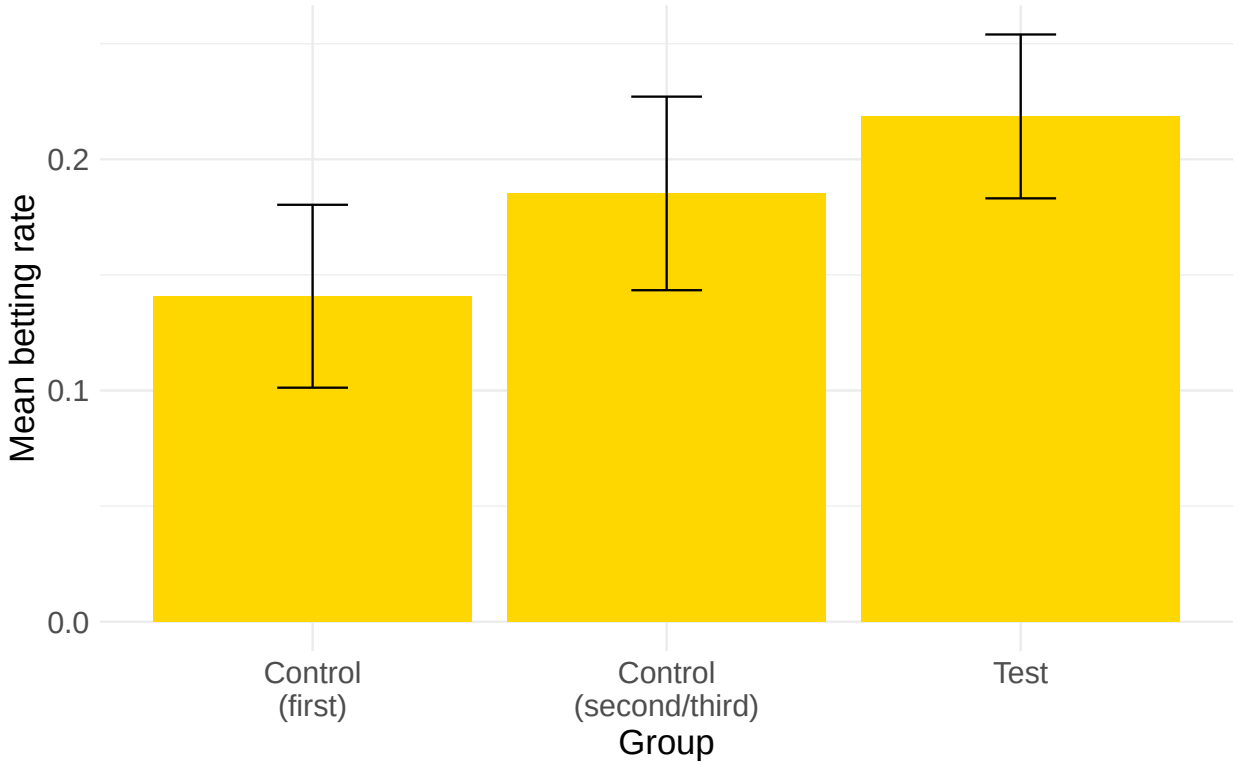

Figure 13: Betting rate in the first or second/third session in a sequence of yellow sessions in the control treatment. Betting rate for the test treatment is shown individually.

Test 5 - first in sequence only

	Beta	SE	z-value	p-value
(Intercept)	-3.846	0.420	-9.154	$< .001$ ***
reward_valueHigh	1.395	0.107	13.014	$< .001$ ***
uncertaintyHigh	0.611	0.099	6.165	$< .001$ ***
treatmentTest	0.679	0.347	1.959	0.05
previous_choice	1.266	0.099	12.739	$< .001$ ***
age	-0.317	0.200	-1.590	0.112
gender2	-0.232	0.340	-0.685	0.494
major2	-0.052	0.426	-0.123	0.902
major4	1.308	0.963	1.358	0.174

Test 5 - first and second in sequence only

	Beta	SE	z-value	p-value
(Intercept)	-3.737	0.423	-8.825	$< .001$ ***
reward_valueHigh	1.349	0.097	13.886	$< .001$ ***
uncertaintyHigh	0.752	0.091	8.253	$< .001$ ***
treatmentTest	0.474	0.346	1.370	0.171
previous_choice	1.275	0.092	13.892	$< .001$ ***
age	-0.258	0.199	-1.295	0.195
gender2	-0.192	0.345	-0.556	0.578
major2	-0.025	0.432	-0.058	0.954
major4	1.343	0.984	1.365	0.172

Controlling for losses

We wanted to see if there was a correlation between the losses people accrued and the betting rate in yellow background sessions. This was meant to represent whether people learned from their mistakes. This was done in a few steps.

First, we checked overall betting rates in yellow over the 6 sequences for control and test. This was simply to see betting over the course of the experiment in general, as a baseline.

Next, we checked two different variables, both related to losses. First, we checked betting rate as a function of cumulative losses (in yellow only). Then, we checked betting rate as a function of cumulative losses in yellow but dividing by the cumulative bets in yellow. In this way, a participant who bets a lot in yellow but luckily does not lose a lot, will have a lower "loss score".

Finally, we plot betting rates in yellow each sequence for participants who with low, medium and high losses in the first sequence. This is meant to show whether high losses in the beginning of the experiment result in different betting patterns throughout.

These four checks are presented in the figures below. We importantly only used cravers for this analysis as others did not bet in yellow more than once.

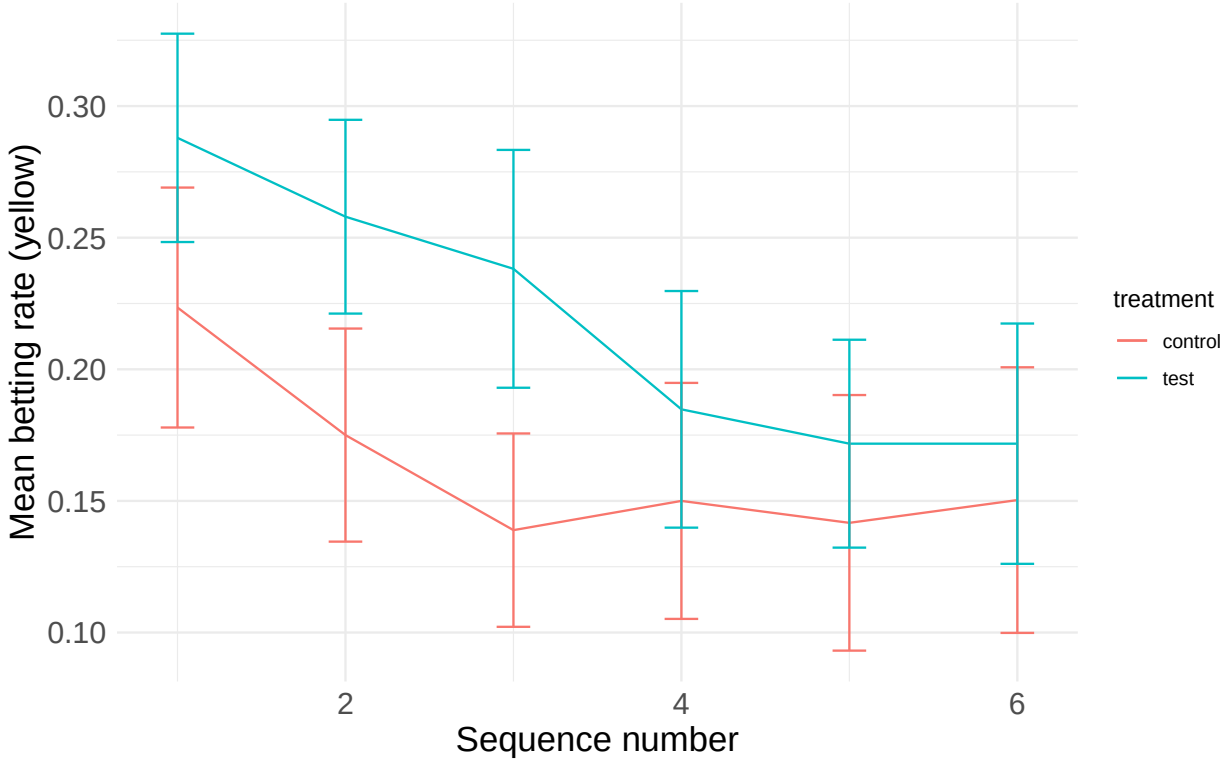

Figure 14: Betting rate in yellow as a function of sequence number in test and control. Error bars are SEM.

Next, we include the variable from figure 16 in test 5 (without separating into bins), meaning we control for the losses participants accrue given how much they bet. A negative coefficient on the variable would mean that people who face unusually high losses given how much they bet, have lower betting rates in yellow throughout the experiment.

To see if the effect differs by treatment, we also include the interaction between treatment and the loss variable.

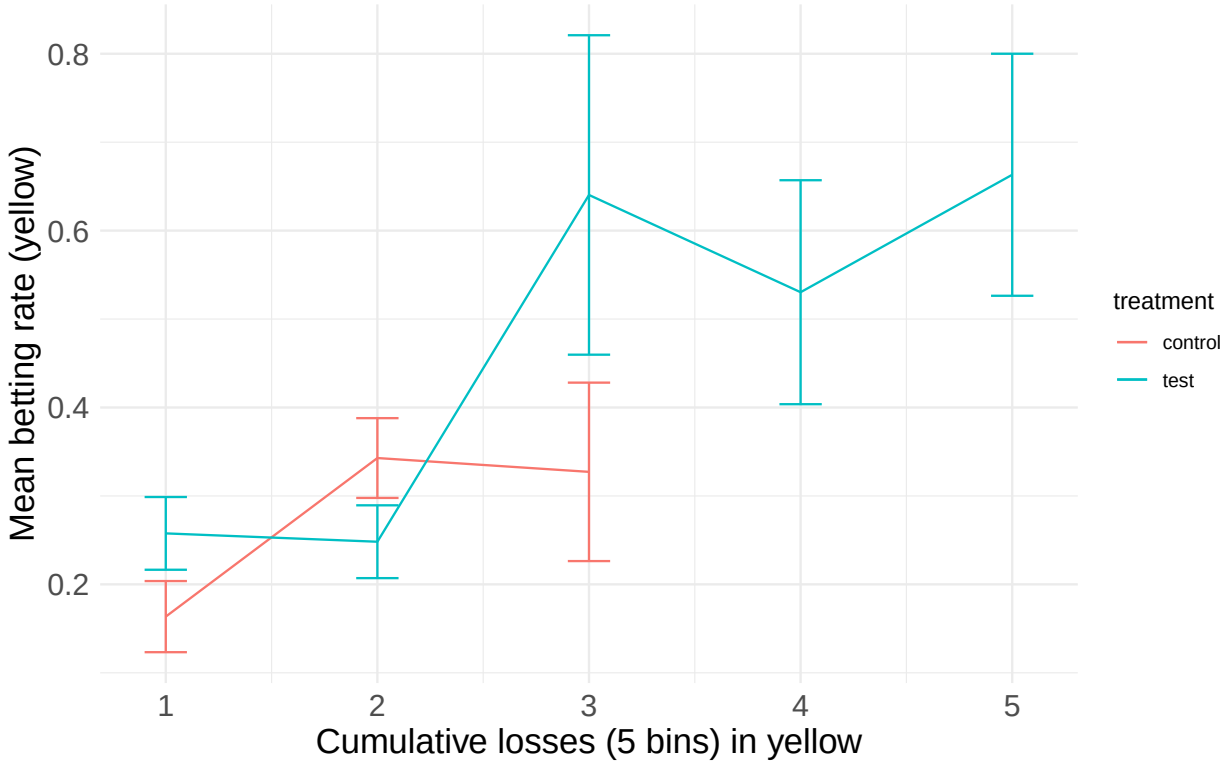

Figure 15: Betting rate in yellow by cumulative losses (in 5 bins) for test and control. Error bars are SEM.

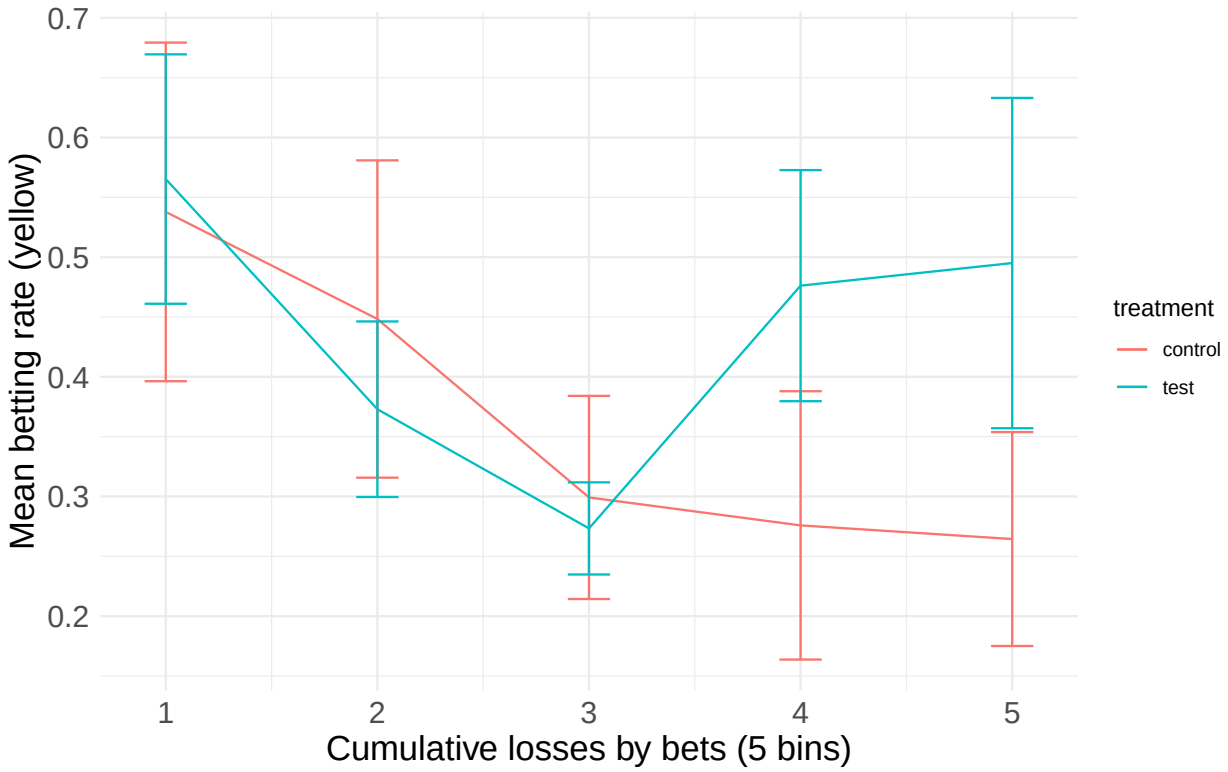

Figure 16: Betting rate by 5 bins representing cumulative losses over cumulative bets. Error bars are SEM.

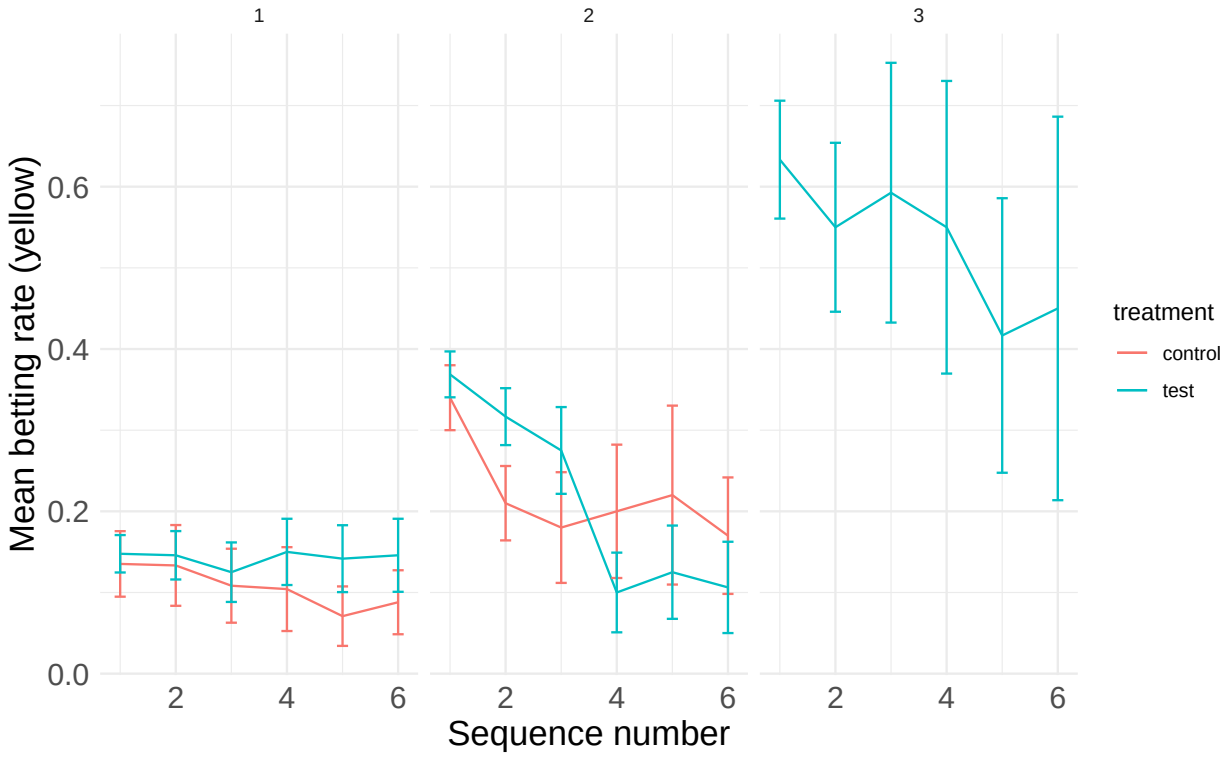

Figure 17: Betting rate in yellow by sequence number. The plot is separated in 3 increasing panes with low (1), medium (2), and high (3) losses in the first sequence.

The lack of significance for these two variables seem to indicate that the losses accrued given betting rates do not impact betting in yellow.

Test 5 - first and second in sequence only

	Beta	SE	z-value	p-value
(Intercept)	-3.544	0.377	-9.398	$< .001$ ***
reward_valueHigh	1.294	0.094	13.697	$< .001$ ***
uncertaintyHigh	0.706	0.089	7.969	$< .001$ ***
treatmentTest	0.225	0.305	0.739	0.46
previous_choice	1.300	0.089	14.602	$< .001$ ***
age	-0.279	0.177	-1.573	0.116
gender2	-0.208	0.303	-0.685	0.493
major2	0.156	0.384	0.408	0.683
major4	1.408	0.887	1.588	0.112
losses_by_bets	-0.062	0.115	-0.544	0.587
treatmentTest:losses_by_bets	-0.123	0.148	-0.826	0.409

First 4 sessions of blue in test/control

We checked the difference in betting rates in the first 4 blue sessions in the test and control treatment separately. This is shown in a bar chart below as well as a t-test checking the difference in betting rates between test and control. Only the first "actual" blue sessions are used. Interspersed sessions and clocks before the experiment (to avoid boredom) were not used.

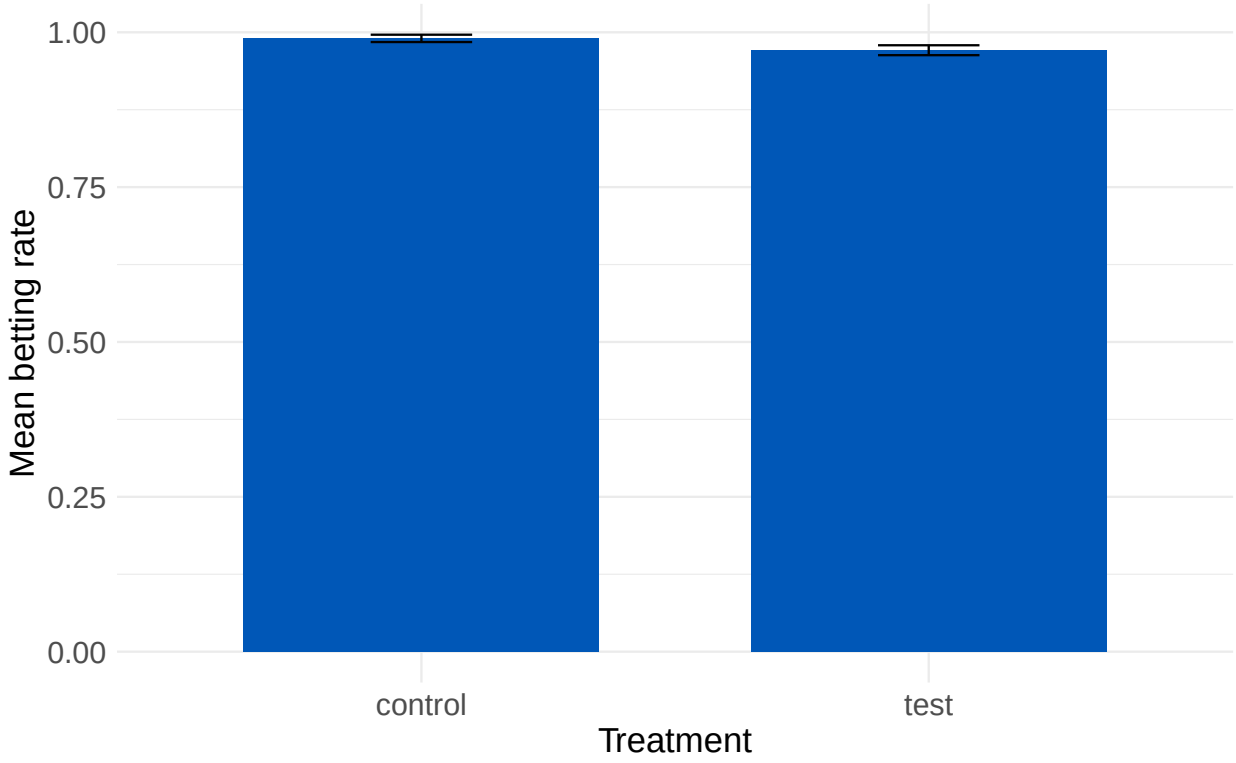

Figure 18: Average betting rates in the first 4 blue sessions for the control and test treatment. Error bars show SEM.

A two-sample t-test comparing the difference in betting rates in the first 4 blue sessions found no difference in mean between the two treatments (Welch two-sample t-test, $t(111) = 1.912$, $p = 0.058$).