Hoven, M., Lebreton, M., van Holst, R.J.: Behavioral and computational signatures of reinforcement learning and confidence biases in gambling disorder

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Supplementary Materials

Types of gambling

All patients with GD were asked to indicate their favourite gambling type, where more than one answer could be indicated. Online gambling was indicated most often as favourite gambling type, followed by casino gambling.

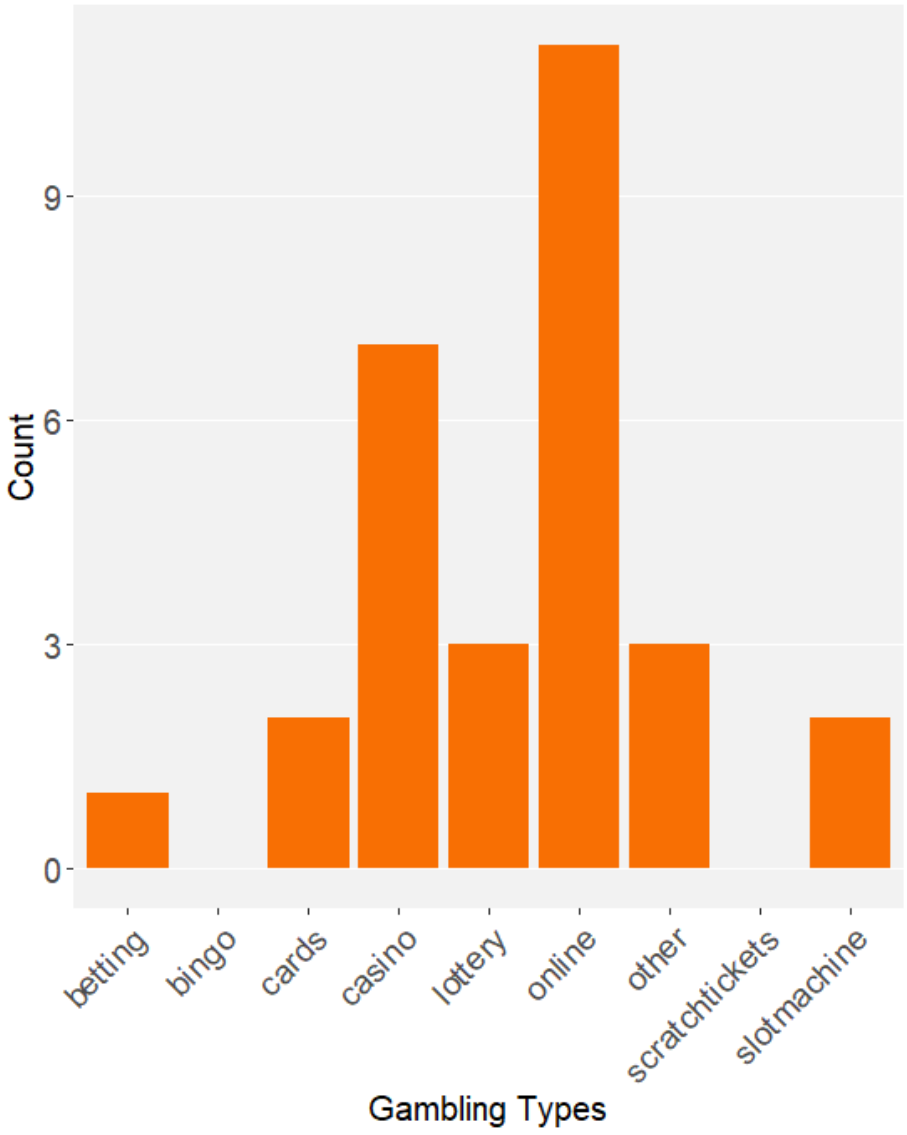

Figure S1: Favourite gambling type as reported in the GD group. Multiple answers were possible.

Parameter recovery

We simulated choice and learning data for 1800 subjects, following Nahuel et al., 2023. We randomly sampled learning model parameters from the theoretical prior distributions that were also used for model fitting. Using these parameters task data including 2 learning sessions of 96 trials and 56 transfer trials were simulated. The task data was then fitted by the same reinforcement learning model (RELASYM), and the parameter recovery was calculated as the correlation between the generative parameter with the recovered parameters.

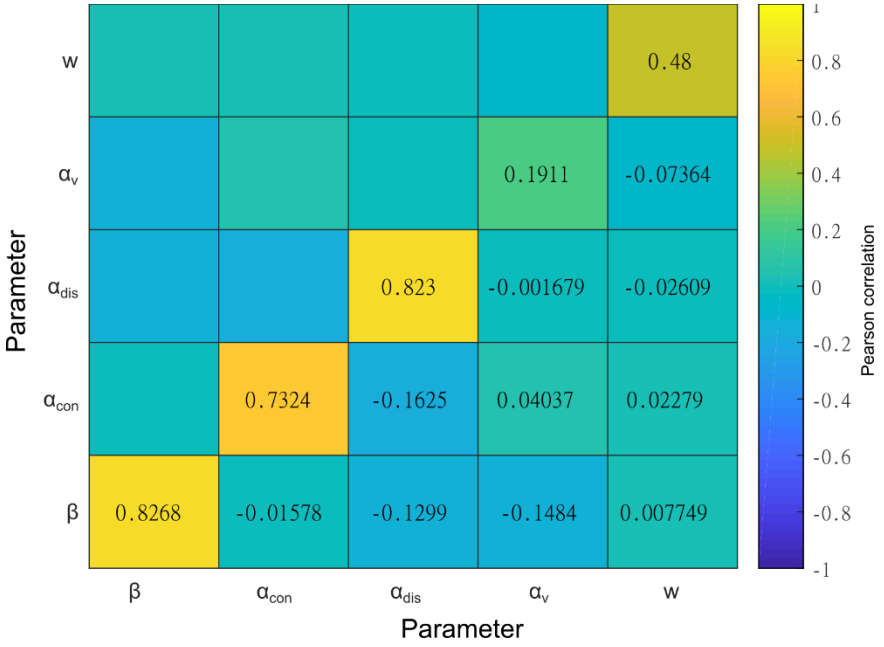

Figure S2: Parameter recovery analysis. Data from 1800 synthetic participants were simulated with the RELASYM model. The diagonal represents correlations between simulated and estimated parameter. The off diagonal represents correlations between estimated parameters.

Comparing control groups

Many previous datasets using the same reinforcement learning paradigm have been collected in student healthy control samples. In order to compare behaviour on this task between a large sample of healthy students and our current HC sample, we leveraged multiple datasets from (Ting et al., 2020). We have used data from Experiment 2-6, all with minor differences in task structure, but with similar conditions and instructions, of which the results were found to be very robust (Salem-Garcia et al., 2023; Ting et al., 2020). These data were collected from a total of 90 independent subjects (5 experiments with 18 subjects each), which we will refer to as the 'Ting group'. To compare the Ting group to our current HC group, we performed similar mixed model analyses compared to our main analyses. First, averages of the behavioral outputs for each participant and condition were calculated. All main effects, two- and three-way interactions were included, together with random intercepts for each subject.

Accuracy was higher in the complete versus partial condition in the Ting group, but not in our HC group (β = -1.77 +- 0.848, t_{318} = -2.08, p = 0.038, post-hoc: Ting: -7.64 +- 1.38, t_{318} = -5.52, p<.001; Hoven: -0.59 +- 3.10. t_{318}=-0.19, p = 0.851). Interestingly, a significant three-way interaction between information, value and group (β = -2.21 +- 0.848, t_{318} = -2.60, p = 0.010) indicated that while in the Ting data, accuracy was significantly higher in gain versus loss conditions specifically in the complete information condition (4.08 +- 1.96, t_{318}=2.09, p=0.038), in the Hoven data accuracy was marginally higher in gain versus loss conditions specifically in the partial information condition (7.99 +- 4.38, t_{318}=1.824, p=0.0691).

In terms of confidence, only a significant value effect was found (β=3.67 +- 0.315, t_{318}=11.63, p<.001), with no differences between groups. For calibration, next to a main effect of value (β=2.854 +- 0.821, t_{318}=3.476, p<.001)) and information (β=1.68 +- 0.82, t_{318}=2.04, p=0.042), a significant three-way interaction between value, information and group was found (β=2.51 +- 0.82, t_{318}=3.05, p=0.002). This suggested that, whereas for the Ting data, overconfidence in the gain condition compared to the loss condition was only significant in the partial condition (11.20 +- 1.90, t_{318}=5.91, p<.001), this effect was only significant in the complete condition in the Hoven data (10.23 +- 4.24, t_{318}=2.41, p=0.016).

Together, this shows that even though there are no main group differences in accuracy, confidence or calibration, there are some divergent patterns emerging when taking into account the task conditions. The current HC group does not seem to replicate two robust effects shown repeatedly using this task in student HC populations: (1) increased accuracy in the complete

versus partial condition, and (2) overconfidence in gain versus loss conditions specifically in the partial information condition.

Comparing GD group to student HC population

We performed a similar exercise, now comparing the GD group to the student HC population from (Ting et al., 2020). In terms of accuracy, a main effect of information indicated higher overall accuracy in the complete condition compared to the partial condition (β=-3.61 +- 0.88, t_{321} = -4.10, p<.001). Moreover, a significant two-way interaction between information and value (β=-2.71 +-0.88, t_{321} = -3.08, p = 0.002) indicated that, in both groups, in the partial condition, accuracy is slightly higher in the loss condition compared to the gain condition (Post-hoc: -6.40 +- 2.49 t_{321}=-2.57, p=0.01). In the complete condition, however, accuracy is marginally higher in the gain compared to loss condition (4.45 +- 2.49, t_{321} = 1.79, p=0.075).

A significant main effect of value on confidence was found, indicating higher confidence for gain compared to loss conditions (β=2.61 +- 0.30, t_{321} = 8.82, p<.001). This difference was significantly bigger in the partial condition compared to the complete condition (β=0.79 +- 0.30, t_{321}=2.67, p=0.008; post-hoc partial condition gain-loss: 6.80 +- 0.837, t_{321}=8.12, p<.001; post-hoc complete condition gain-loss: 3.64 +- 0.84 t_{321}=4.35, p<.001). Interestingly, and similar to our main results, the difference in confidence between gain and loss was bigger in the Ting group compared to the GD group (β=0.60 +- 0.30, t_{321}=2.67, p = 0.045; post-hoc Ting group gain-loss: 6.41 +- 0.49, t_{321} = 12.97, p<.001; post-hoc GD group gain-loss: 4.01 +- 1.08, t_{321} = 3.75, p < .001).

Comparing calibration, we found a main effect of value, indicating more overconfidence in gain compared to loss conditions (β=3.10 +- 0.85, t_{321}=3.65, p<.001), a main effect of information, indicating more overconfidence in partial compared to complete information (β=3.20 +- 0.85, t_{321}=3.77, p<.001). A two-way interaction effect between value and information (β=3.50 +- 0.85, t_{321}=4.13, p<.001) indicated that this overconfidence in gain compared to loss was only significant in the partial condition (13.20 +- 2.40, t_{321}=5.51, p<.001) and not in complete condition (-0.81 +- 2.40, t_{321}=-0.34, p=0.736), for both groups.

Taken together, there are some small differences in effects when comparing the GD group to our current HC group or when comparing to the Ting group. In our main analyses, small three-way interactions between value, information and group on both accuracy and calibration were found, which were not replicated when analysing the Ting group. Importantly, for both control groups it was found that the difference between gain and loss conditions in confidence was larger in the control groups, contrary to our expectations.

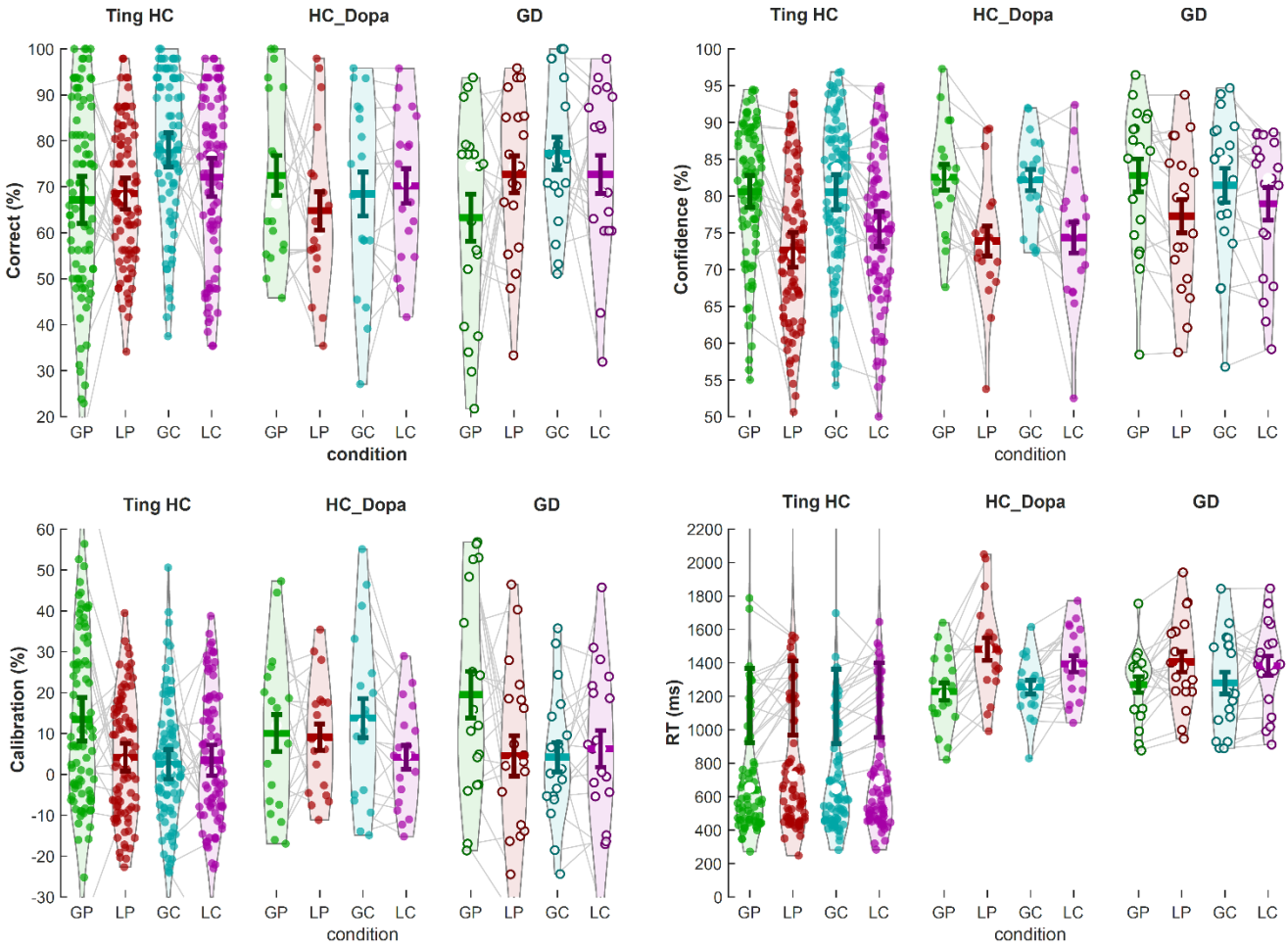

Figure S3: Behavioral measures of learning task, (A) accuracy, (B) confidence, (C) calibration. Shown are individual averaged responses per condition. Dots represent individual data points, which are connected per subject. Error bars represent the sample mean +- standard error of the mean. GP: Gain-Partial, LP: Loss-Partial, GC: Gain-Complete, LC: Loss-Complete, HC: Healthy Controls, GD: Gambling Disorder. Ting HC are taken from Experiment 2-5 from (Ting et al., 2020)