Point-by-point reply to the reviewer's comments

Manuscript No. ade7972

"Dynamic prospect theory: two core decision theories coexist in the gambling behavior of monkeys and humans"

We greatly appreciate the further helpful comments from the first reviewers. We have carefully revised our manuscript accordingly. Below, we provide point-by-point responses to reviewers' comments.

Reviewers' comments:

Reviewer: 1

The authors have considerably amended their manuscript according to reviewers' suggestions, adding new sections/parts and several (robustness check) analyses and rephrasing parts where findings might have been overstated. Their idea and findings are still interesting and more precise now, but the additional analyses also demonstrate some weaknesses and inconsistencies in their results. I also have remaining open questions and concerns regarding the authors' replies to some of the comments raised, as outlined in the following.

> We appreciate further comments from the first reviewer. We think that these comments allowed us to improve our manuscript.

• According to the authors' reply to main point 4 and to some of the further points raised, they estimated models across all human participants, i.e. as if the 70 participants were one and the same person. This should at least be mentioned more clearly and the lacking consideration of between-participant variance be discussed as a potential limitation. Looking at their newly added psychometric functions in their reply to comment 6e, I wonder whether one reason for why P2 might work well in humans could be because to some degree it best captures interindividual differences (rather than trial-to-trial dynamics). In addition, the figure that the authors included in their reply to comment 6e doesn't seem to have been included in the manuscript – It might be useful to do this.

> The reviewer said that “the authors estimated models across all human participants, i.e. as if the 70 participants were one and the same person. This should at least be mentioned more clearly and the lacking consideration of between-participant variance be discussed as a potential limitation.” We tried to make our approach to the analysis of the human data clearer in the current version, in Materials and Methods. We say:

“**Statistical analysis**

Stata was used for statistical analyses. All statistical tests were two tailed. The structural models were estimated for each monkey separately. For human data, due to a smaller number of choices, we use representative agent approach, i.e. estimate one model for all 70 participants with standard errors clustered at the participant level. A limitation of this approach is that we did not investigate individual heterogeneity in behavior within human species."

Following referee’s suggestion, we included the psychometric choice figures in the supplementary material as Figure S1 and mentioned in the result section as follows.

Results, P10

“We also checked the degree of stochasticity (parameter β in Table 1) and psychometric choice functions (Fig. S1) for our participants.”

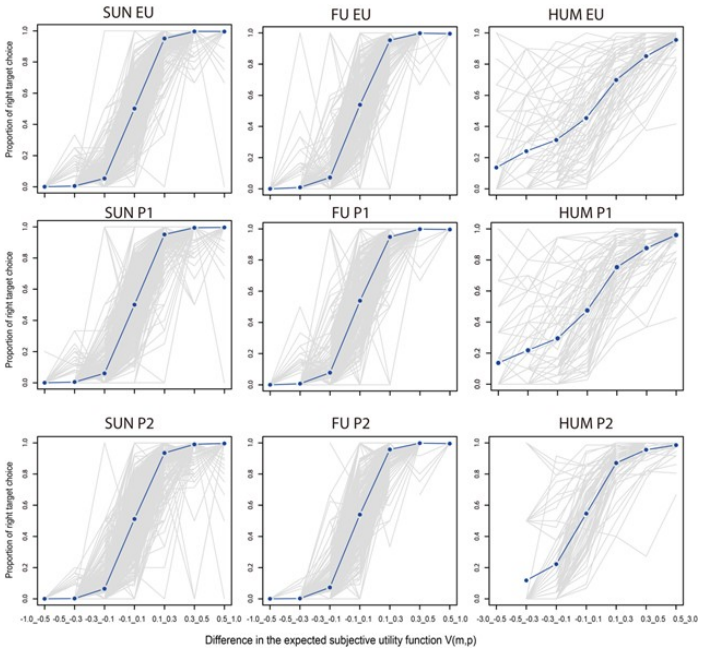

Figure S1.

Psychometric choice functions. x-axis represents the difference in the expected subjective utility (Page 36-37 in the main text) between the right and left target. The y-axis is the proportion of right target choices that participants made for each difference. The blue lines represent choice probability for all data and gray lines separately for each block for monkey data and for each participant for human data.

• Major point 5: The authors now report correlations between actual and recovered parameters, but I cannot seem to find that they report the frequencies with which the data generating model was recognized by model comparisons. Or am I missing something?

> Thank you for noticing and bringing this up! We focused on parameter recovery so much that we missed the request for model recovery. We included these new results in the "*Parameter and model recovery"* section (note the change of the name of the section from "*Parameter recovery"*).

"A separate question is how often the data generating model is recognized by model comparisons. To answer this question, we first use our simulated dataset to check how often EU or P2 chooser would be incorrectly identified as separate RPE chooser. We found that this never happens. When the generative choosers have EU preferences, BIC of the EU model fit is always lower than that of separate RPE model. Similarly, when the generative choosers have P2 preferences, P2 is always identified as a better model than separate RPE according to BIC. After checking these static prospect theory models, we checked how often the choosers with separate RPE preferences are correctly identified according to BIC. We found that out of our 40 simulated choosers, none were ever mistaken for EU choosers. However, we would mistakenly classify eight as P2 according to BIC For these simulated participants, the BIC differences between the models were minimal (Fig. S3). Indeed, only one of them would be classified as P2 chooser according to AIC that applies lower penalty for extra parameters. Overall, we concluded that it is very unlikely that we would classify EU or P2 choosers as separate RPE choosers but it is possible to sometimes mistake separate RPE choosers for P2 choosers due to the extra parameter penalty applied by BIC and to a lesser extent by AIC."

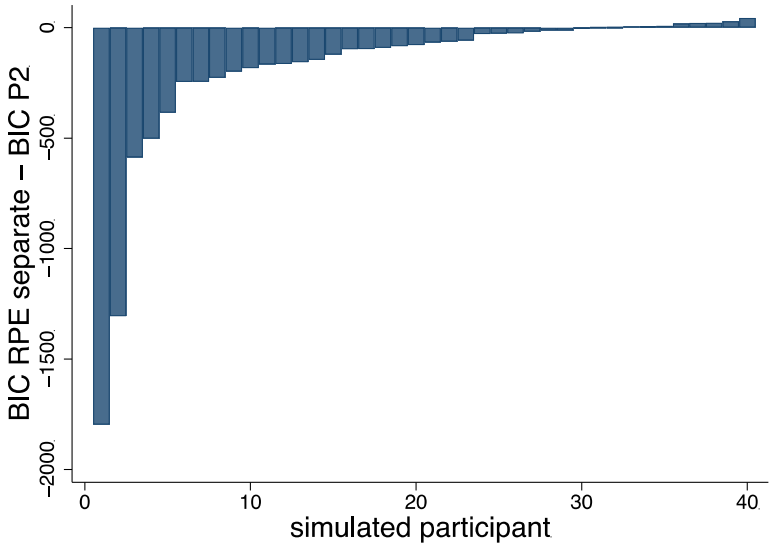

Figure S3.

Model recovery. y-axis captures the difference in BIC of the separate RPE (P2-based) and P2 models. Both models are estimated using simulation data of 40 individuals assumed to have preferences as in separate RPE model.

• The authors now state the role of the tone in the monkey experiment more clearly. I think this should be mentioned as a difference between the monkey and human versions of the tasks, at least in the discussion section. Moreover, one wonders why reward delivery in the human version was not also preceded by a tone in order to make the tasks even more comparable. It might not make a difference after all, but theoretically/potentially it could.

> As the reviewer suggests, we added the following description in the discussion.

We chose no use of sound in the human study because we collected data online and could not experimentally control that the sound is correctly delivered to human participants. Even if participants had their headphones on, we would not be able to control volume. Therefore, for consistency across human participants, we did not use sound. We make this difference more explicit in the current version of the manuscript.

Experimental setting for humans, P9-10

"We note that aggregated data analysis of human behavior is a standard procedure in the economic literature (33). Additionally, the differences between the two experiments were as follows: 1) monkeys decided on liquid rewards, whereas humans decided on monetary rewards; 2) we collected numerous decisions from two monkeys and a relatively small number of individual decisions from many human participants (although still a large number of decisions for a human study); 3) monkeys learned the magnitudes and probabilities associated with the visual pie-chart lottery representation through experience before data collection, whereas human participants learned the meaning of the visual pie charts by reading the instructions; and 4) reward delivery was not preceded by a tone for human participants."

• Please mention the relation to the previous studies using the same dataset in the introduction at a more general description, in addition to a more specific description in the results section.

> Thank you for the reviewer's really useful comment. We added the following description in the introduction.

Introduction, P6

"Previous studies have implied that findings from monkey research expand our understanding of human behavior by enabling researchers to understand the evolutionary roots of choice, as well as to conduct research that is not easily feasible with human participants. For example, we have previously described utility and probability weighting functions in monkeys using the same dataset in the present study (*24*). Leveraging the use of the same experimental paradigm for both species enabled us to compare monkey and human behavior through the lens of two major decision theories and to contribute to the long-standing dispute on the extent to which monkeys are a good model for human decision-making."

• "settle matters under debate in the literature" # Could the authors give relevant examples?

> Thank you for the reviewer's comment. We added the following description.

Introduction, P6

"A fair comparison between monkeys and humans helps settle matters under debate in the literature (e.g. whether monkeys and humans have similar or different risk preferences),"

• Minor point 8: I meant their verbal description is identical, which could be a bit confusing.

> Thank you for clarifying this. We now say:

Methods, P38

"4. P1: prospect theory with w(p) with one parameter as in Prelec, 1998 (63)

$$V(m,p) = \exp\left(-(-\log p)^{\gamma}\right)m^{\alpha}$$

5. P2: prospect theory with w(p) with two parameters as in Prelec, 1998 (63)

$$V(m,p) = \exp\left(-\delta(-\log p)^{\gamma}\right)m^{\alpha}$$ "

• Minor point 9: It would help to nevertheless include additional plots covering the whole ranges as supplementary figures.

> As the reviewer suggest, we added the plot of the utility function for humans for the range up to $5 as Figure S4 in the supplement.

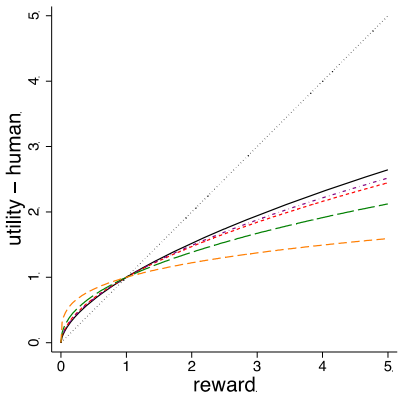

Figure S4.

Illustration of the estimated utility functions in all models for humans covering the entire range of reward. Gray, black, red, purple, green, and orange dashed lines indicate EV, EU, TK, P1, GE, and P2 models, respectively.

• Minor point 13: Maybe better “may help explain”, as now this sentence sounds as if this was the only type of dynamics that could possibly happen.

> This sentence now reads: “The existence of such dynamic changes in lottery valuations may help explain the decision-by-decision dynamics in risky choices.”

• The authors talk about “optimism” at some parts in their manuscript, especially now also in their Teaser. Can the observed behavior with certainty be attributed to “optimism”? It appears that a bit more care is warranted with using this term.

> We changed the teaser to “After lucky wins, monkeys and humans have more optimistic beliefs about the odds of winning which leads to more risk taking” which we hope makes the meaning of optimism clearer. We follow Wakker (2001) who axiomatically defines optimism as concavity of the probability weighting function and pessimism as convexity. Abdellaoui et al. (2010) show that not only elevation but also (less intuitively) attractiveness parameters of the probability weighting contribute to optimism and pessimism. We could have rewritten our conclusions in terms of the elevation of the probability weighting function changing rather than optimism, but we found that version less intuitive and accessible.

Wakker, P. P. (2001). Testing and characterizing properties of nonadditive measures through violations of the sure-thing principle. *Econometrica, 69*, 1039–1059.

Abdellaoui, M., L’Hairdon, O., and Zank H. (2010). Separating curvature and elevation: A parameteric probability weighting function. *Journal of Risk and Uncertainty 41,* 39-65.

Reviewer: 2

No further comments.