

Exogenous testosterone increases the audience effect in healthy males: evidence for the social status hypothesis

Yin Wu, Yinhua Zhang, Jianxin Ou, Yang Hu and Samuele Zilioli

Article citation details

Proc. R. Soc. B **287**: 20200976.

<http://dx.doi.org/10.1098/rspb.2020.0976>

Review timeline

Original submission: 29 April 2020

Revised submission: 23 June 2020

Final acceptance: 24 June 2020

Note: Reports are unedited and appear as submitted by the referee. The review history appears in chronological order.

Review History

RSPB-2020-0976.R0 (Original submission)

Review form: Reviewer 1

Recommendation

Accept with minor revision (please list in comments)

Scientific importance: Is the manuscript an original and important contribution to its field?

Good

General interest: Is the paper of sufficient general interest?

Good

Quality of the paper: Is the overall quality of the paper suitable?

Excellent

Is the length of the paper justified?

Yes

Should the paper be seen by a specialist statistical reviewer?

No

Do you have any concerns about statistical analyses in this paper? If so, please specify them explicitly in your report.

No

It is a condition of publication that authors make their supporting data, code and materials available - either as supplementary material or hosted in an external repository. Please rate, if applicable, the supporting data on the following criteria.

Is it accessible?

Yes

Is it clear?

Yes

Is it adequate?

Yes

Do you have any ethical concerns with this paper?

No

Comments to the Author

The authors in this manuscript investigate if testosterone application influences the willingness to donate money to a charity organization depending on public versus private donations. This is of special interest since higher donations in the public condition likely represent a socially desirable behavior and may be related to an improved social status if participants donate a high amount of money.

Indeed the authors find that participants in the testosterone group donate more money in the public condition. Thereby they provide additional support for the hormone's influence on status driven motivation. In the current study, the authors thus add some very interesting evidence on the hypothesis that testosterone increases behaviors that support the social status by manipulating if the social status is (potentially) evaluated by the presence of another person or not. The manuscript has a high quality and the study is well-designed.

I have a few questions and comments related to some study details. I will list my comments below.

C 1: What was the maximum participants could earn and the maximum they could donate? Furthermore, I was not completely sure: Would the money really be donated to the charity organization and were participants explicitly informed about this? It would be great to state this clearly.

C 2: Introduction: Why do the authors mention autism? This is not really closely linked to the focus of the study and it is a little confusing since (circulating) testosterone is also sometimes linked to autism (high T = more autistic traits). The way the authors state their hypotheses, I think this would not match with the link of high autistic traits = high testosterone. I do agree with the authors hypotheses for many reasons, and the relationship of T and autism might be much more complicated than "high T = high autistic traits = low donations", but I would suggest to not emphasize autism in the introduction since this may lead to unnecessary confusion. Furthermore the authors do not discuss the AQ later on.

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Also, related to the public condition: What was the gender of the research assistant watching the participants?

C 5: Why was RT log-transformed?

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C 8: The authors also speculate on neural correlates and mention reward related brain regions. If reward would be the primary reason for T effects, than higher T should be related with higher rewards for participants not with the audience effect. Since this effect is more about integrating the perspective of another person, regions that are related to the "social brain" such as the default mode network could be of interest. This has not been investigated broadly so far, but there are some studies, indicating that this network may be affected by T administration (for example see <https://doi.org/10.1016/j.neuropharm.2019.01.006> or DOI: 10.1530/endoabs.41.EP958).

Review form: Reviewer 2

Recommendation

Accept with minor revision (please list in comments)

Scientific importance: Is the manuscript an original and important contribution to its field?

Excellent

General interest: Is the paper of sufficient general interest?

Excellent

Quality of the paper: Is the overall quality of the paper suitable?

Excellent

Is the length of the paper justified?

Yes

Should the paper be seen by a specialist statistical reviewer?

No

Do you have any concerns about statistical analyses in this paper? If so, please specify them explicitly in your report.

No

It is a condition of publication that authors make their supporting data, code and materials available - either as supplementary material or hosted in an external repository. Please rate, if applicable, the supporting data on the following criteria.

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This is a very well written paper. I adds further evidence to the more nuanced role of T in modulating human behavior. I have only some relatively minor suggestions for changes.

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p. line 15. Good - but it would be very helpful to know whether any of the individual difference variables interacted with the public vs. private manipulation and/or drug condition. This could easily be reported in the supplementary materials and discussed as "exploratory analyses". This suggestion is especially relevant given the work by Bird et al (2019) showing that effects of T on cooperation (public goods game) depend on context (fast vs. slow decisions) and personality (high vs. low risk personality traits) see: <https://www.nature.com/articles/s41386-018-0220-8?draft=marketing>

Decision letter (RSPB-2020-0976.R0)

19-Jun-2020

Dear Dr Wu

I am pleased to inform you that your manuscript RSPB-2020-0976 entitled "Exogenous testosterone increases the audience effect in healthy males: Evidence for the social status hypothesis" has been accepted for publication in Proceedings B.

The referee(s) have recommended publication, but also suggest some minor revisions to your manuscript. Therefore, I invite you to respond to the referee(s)' comments and revise your manuscript. Because the schedule for publication is very tight, it is a condition of publication that you submit the revised version of your manuscript within 7 days. If you do not think you will be able to meet this date please let us know.

To revise your manuscript, log into <https://mc.manuscriptcentral.com/prsb> and enter your Author Centre, where you will find your manuscript title listed under "Manuscripts with Decisions." Under "Actions," click on "Create a Revision." Your manuscript number has been appended to denote a revision. You will be unable to make your revisions on the originally submitted version of the manuscript. Instead, revise your manuscript and upload a new version through your Author Centre.

When submitting your revised manuscript, you will be able to respond to the comments made by the referee(s) and upload a file "Response to Referees". You can use this to document any changes you make to the original manuscript. We require a copy of the manuscript with revisions made since the previous version marked as 'tracked changes' to be included in the 'response to referees' document.

Before uploading your revised files please make sure that you have:

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- 4) A media summary: a short non-technical summary (up to 100 words) of the key findings/importance of your manuscript.

- 5) Data accessibility section and data citation

It is a condition of publication that data supporting your paper are made available either in the electronic supplementary material or through an appropriate repository.

In order to ensure effective and robust dissemination and appropriate credit to authors the dataset(s) used should be fully cited. To ensure archived data are available to readers, authors should include a 'data accessibility' section immediately after the acknowledgements section. This should list the database and accession number for all data from the article that has been made publicly available, for instance:

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- Phylogenetic data: TreeBASE accession number S9123

- Final DNA sequence assembly uploaded as online supplemental material
- Climate data and MaxEnt input files: Dryad doi:10.5521/dryad.12311

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If you wish to submit your data to Dryad (<http://datadryad.org/>) and have not already done so you can submit your data via this link

[http://datadryad.org/submit?journalID=RSPB&manu=\(Document not available\)](http://datadryad.org/submit?journalID=RSPB&manu=(Document%20not%20available)) which will take you to your unique entry in the Dryad repository. If you have already submitted your data to dryad you can make any necessary revisions to your dataset by following the above link.

Please see <https://royalsociety.org/journals/ethics-policies/data-sharing-mining/> for more details.

6) For more information on our Licence to Publish, Open Access, Cover images and Media summaries, please visit <https://royalsociety.org/journals/authors/author-guidelines/>.

Once again, thank you for submitting your manuscript to Proceedings B and I look forward to receiving your revision. If you have any questions at all, please do not hesitate to get in touch.

Sincerely,

Dr Sasha Dall

mailto:proceedingsb@royalsociety.org

Associate Editor

Board Member: 1

Comments to Author:

The paper describes an experiment in which the researchers test whether application of testosterone gel to participants affects their levels of altruism as tested by a 'donation task' (an experiment in which the participants are asked to accept or reject monetary transfers to charities that come at personal cost in either the presence or absence of an audience). The experiment provides support for a hypothesis known as the "Social Status Hypothesis" -- that increases in testosterone will shape the willingness of an individual to act altruistically, and that this willingness will be contingent on whether the individual is acting privately or publicly. The paper is well written, and analyses sound. The paper was reviewed by two field expert referees, who each assess the quality of the paper as excellent, but each of whom raise some very insightful comments and queries that require careful attention by the authors prior to publication.

Reviewer(s)' Comments to Author:

Referee: 1

Comments to the Author(s)

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Referee: 2

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Author's Response to Decision Letter for (RSPB-2020-0976.R0)

See Appendix A.

Decision letter (RSPB-2020-0976.R1)

24-Jun-2020

Dear Dr Wu

I am pleased to inform you that your manuscript entitled "Exogenous testosterone increases the audience effect in healthy males: Evidence for the social status hypothesis" has been accepted for publication in Proceedings B.

You can expect to receive a proof of your article from our Production office in due course, please check your spam filter if you do not receive it. PLEASE NOTE: you will be given the exact page length of your paper which may be different from the estimation from Editorial and you may be asked to reduce your paper if it goes over the 10 page limit.

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All supplementary materials accompanying an accepted article will be treated as in their final form. They will be published alongside the paper on the journal website and posted on the online figshare repository. Files on figshare will be made available approximately one week before the accompanying article so that the supplementary material can be attributed a unique DOI.

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Thank you for your fine contribution. On behalf of the Editors of the Proceedings B, we look forward to your continued contributions to the Journal.

Sincerely,

Proceedings B

<mailto:proceedingsb@royalsociety.org>

Appendix A



深圳大學
SHENZHEN UNIVERSITY

24 June, 2020

Dear Dr. Dall,

Thank you for your feedback on our manuscript entitled “Exogenous testosterone increases the audience effect in healthy males: Evidence for the social status hypothesis” (RSPB-2020-0976). We were delighted to learn that the paper is acceptable pending some minor revision. In the attached response to the reviewer, we address the comments raised by the reviewers. Changes have been highlighted in yellow in the manuscript, while itemized responses are reported in the attached response to reviewers.

We look forward to hearing from you.

Yours sincerely,

A handwritten signature in black ink that reads "Yin Wu".

Dr. Yin Wu

School of Psychology

Shenzhen University

Nanhai Blvd. 3688

Shenzhen, Guangdong, China 518060

Tel: 86 15017920128

Email: yinwu0407@gmail.com

Associate Editor

Board Member: 1

Comments to Author:

The paper describes an experiment in which the researchers test whether application of testosterone gel to participants affects their levels of altruism as tested by a 'donation task' (an experiment in which the participants are asked to accept or reject monetary transfers to charities that come at personal cost in either the presence or absence of an audience). The experiment provides support for a hypothesis known as the "Social Status Hypothesis" -- that increases in testosterone will shape the willingness of an individual to act altruistically, and that this willingness will be contingent on whether the individual is acting privately or publicly. The paper is well written, and analyses sound. The paper was reviewed by two field expert referees, who each assess the quality of the paper as excellent, but each of whom raise some very insightful comments and queries that require careful attention by the authors prior to publication.

We thank the associate editor for his/her positive remarks. We listed the itemized responses below. Changes have been highlighted in yellow in the manuscript.

Reviewer(s)' Comments to Author:

Referee: 1

Comments to the Author(s)

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We thank the reviewer for his/her positive feedback and helpful comments, which helped us improve the manuscript.

I have a few questions and comments related to some study details. I will list my comments below.

Question 1: What was the maximum participants could earn and the maximum they could donate? Furthermore, I was not completely sure: Would the money really be donated to the charity organization and were participants explicitly informed about this? It would be great to state this clearly.

Response 1: We have added additional information about the donation task on Page 6, “we orthogonally manipulated the amount of money donated to the charity (range: RMB 4 to 40, in incremental steps of RMB 4) and the monetary cost incurred by the participants (range: RMB 1 to 10, in incremental steps of RMB 1)”. We also specified that participants were explicitly informed at the beginning of the study that their decision on a random trial would be implemented. We also clarified that money were donated to the charity organization through Wechat Pay, which is a widespread mobile payment tool used by China. We have reported this information on Page 6, “Participants were endowed with 15 Yuan and were told at the beginning of the study that at the end of the experiment one trial would be randomly selected and their decision on that trial would be implemented. For example, in a trial in which the participant had incurred a 9 Yuan cost for a 40 Yuan benefit for the charity, the participant gained 6 (i.e., 15 - 9) Yuan and the charity gained 40 Yuan. At the end of the experiment, participants were

asked to make the donation ($M = 18.31$, $SD = 12.52$, range = 0 - 40) in agreement with the selected trial to the Help the Orphan with Rare Disease organization through a mobile App (i.e., Wechat Pay). Thus, the donation task was incentive-compatible.”

Question 2: Introduction: Why do the authors mention autism? This is not really closely linked to the focus of the study and it is a little confusing since (circulating) testosterone is also sometimes linked to autism (high T = more autistic traits). The way the authors state their hypotheses, I think this would not match with the link of high autistic traits = high testosterone. I do agree with the authors hypotheses for many reasons, and the relationship of T and autism might be much more complicated than “high T = high autistic traits = low donations”, but I would suggest to not emphasize autism in the introduction since this may lead to unnecessary confusion. Furthermore the authors do not discuss the AQ later on.

Response 2: We thank the reviewer for this suggestion. We have acted upon it and removed the discussion concerning autism from the Introduction.

Question 3: Why was a time limit (of 5000 seconds) applied; how could such a time pressure affect the choices?

Response 3: Setting a time limit (5000 ms or 5 seconds) served two purposes. First, it was necessary to have the task continue in case participants did not respond to the trial at hand. Second, it helped standardize exposure to each trial (i.e., all participants had the same time limit to respond to each trial). Previous comparable studies used similar time settings (Izuma, Matsumoto, Camerer, & Adolphs, 2011; Izuma, Saito, & Sadato, 2010; Obeso, Moisa, Ruff, & Dreher, 2018; Qu, Météreau, Butera, Villeval, & Dreher, 2019). In our study, the mean response time was 924 ms and the SD was 467 ms. In total, there were 105 trials (0.19% of total trials) in which participants failed to respond within 5 seconds. These trials were removed from the analyses. This information is now reported on Page 8. On page 14, we have acknowledged the possibility that time

pressure might influence participants' choices, particularly in the context of a testosterone administration study.

Question 4: I think the idea to fake a program crash in order to induce the public condition realistically is very creative and well-done, because participants would not be aware of the two conditions they were in. However, such a manipulation may induce additional effects, e.g. participants may not be sure if their decision will be really used as input (e.g. another technical error) or they may feel sorry for the experimenters, which in consequence may induces higher empathy? Perhaps the authors may elaborate if or how the fact that participants were not sure if the program was working may have affected the public condition? Did they perhaps ask participants why they chose other donation levels in the public condition?

Also, related to the public condition: What was the gender of the research assistant watching the participants?

Response 4: In the Discussion (page 14), we have now acknowledged that our staged program crash might have influenced people's decisions.

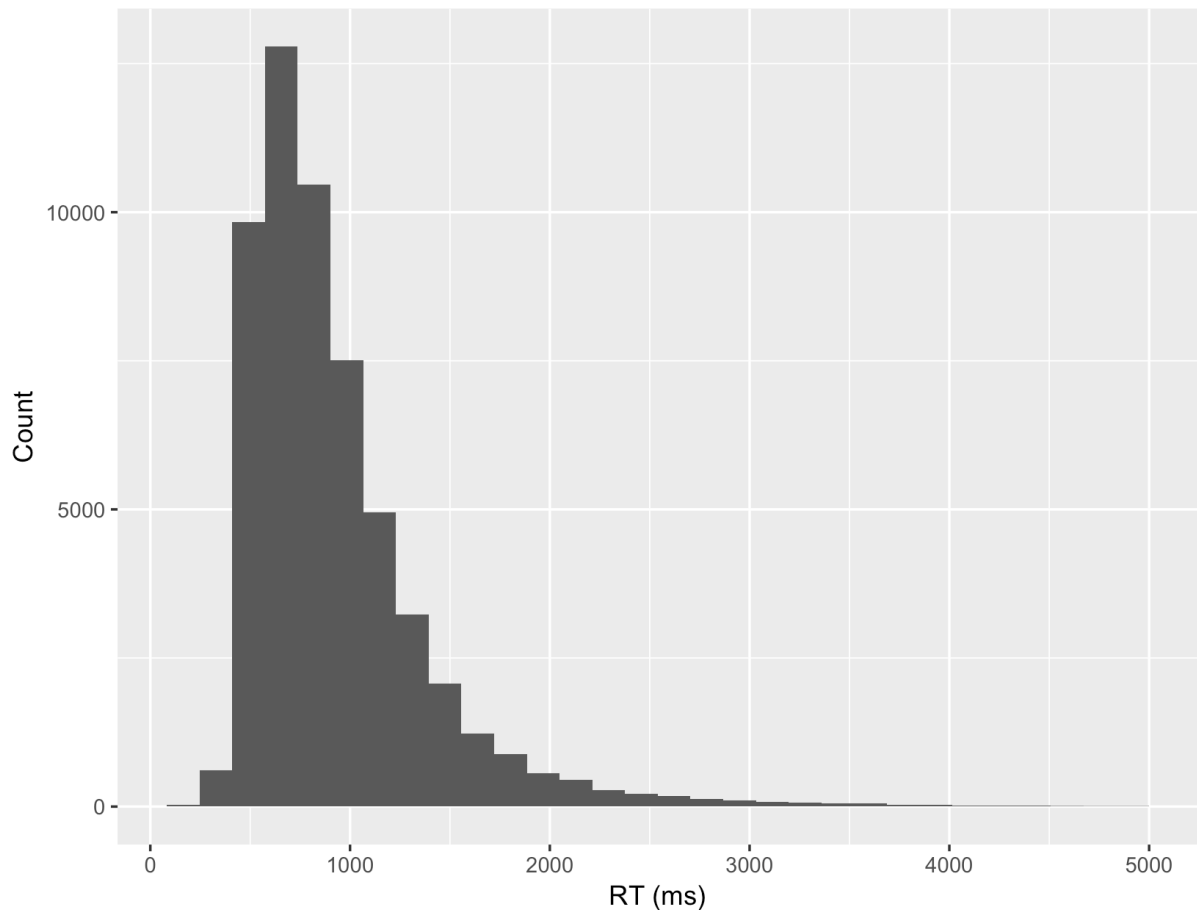
“Second, it is possible that the staged program crash used in our experiment to induce the public condition might have influenced participants' decisions. For example, some participants might have felt sorry for the experimenter and that could have influenced their decision in the task. Future research employing alternative ways to induce the public condition are needed to rule out this possibility and corroborate our findings.”

Participants were not asked why they chose other donation levels in the public condition.

A male research assistant was used in the public condition. We have now added this information on Page 7.

Question 5: Why was RT log-transformed?

Response 5: We used log-transformed response time due to its skewed distribution (see below); we have mentioned this on Page 9.



Question 6: The T group made higher donations in the public condition, but how about RT data? Did the T group also react faster in the public condition? If not, how does this oppose the hypothesis or how why would the hypotheses be specific for the amount of money that is donated and not for RT?

Response 6: We have reported results concerning the response time on Page 11-12 and in Table S4 of the Supplementary Material. Participants responded faster in the public ($M \pm SD$: 899 ± 440 ms) compared to the private condition (950 ± 491 ms), $b = -0.044$,

$SE = 0.004$, $Z = -11.426$, $p < .001$, corroborating the social facilitation effect shown in past research using a similar paradigm (Izuma et al., 2011).

We did not have specific hypotheses regarding the link between response time and prosociality. There is increasing recognition that the use of response time to infer prosocial behaviour (i.e., reverse inference) is problematic as it does not take into account other sources of variability in the data, see Krajbich, Bartling, Hare, & Fehr, 2015.

Question 7: In the discussion, the authors report the findings of Cheng and colleagues showing a relationship of T and prestige. However, this is unrelated to the current study, since high T was an outcome of higher prestige, while in this study T was manipulated. While the study is interesting, I do not see how this study would fit in the discussion of the current results. The authors in this current study cannot be sure that participants enhanced their prestige by donating more money.

Response 7: We agree with the reviewer that the literature on testosterone and prestige did not fit well in the Discussion of the current results. We have now removed Cheng et al.'s study from the Discussion.

Question 8: The authors also speculate on neural correlates and mention reward related brain regions. If reward would be the primary reason for T effects, than higher T should be related with higher rewards for participants not with the audience effect. Since this effect is more about integrating the perspective of another person, regions that are related to the “social brain” such as the default mode network could be of interest. This has not been investigated broadly so far, but there are some studies, indicating that this network may be affected by T administration (for example see <https://doi.org/10.1016/j.neuropharm.2019.01.006> or DOI: 10.1530/endoabs.41.EP958).

Response 8: We appreciate the reviewer's suggestion and have now incorporated the suggested reference in the manuscript (Page 13-14).

“Recent work by Wagels and colleagues [45] showed that testosterone administration increased brain activity in the default brain network, which is active when individuals process social information [46]. In addition to the reward system, the default brain network might also be involved in explaining the behavioural findings reported here; however, this hypothesis awaits empirical testing.”

Referee: 2

Comments to the Author(s)

This is a very well written paper. I adds further evidence to the more nuanced role of T in modulating human behavior. I have only some relatively minor suggestions for changes.

We thank the reviewer for his/her positive remarks.

Question 1: p 3 line 14 ".. however, has challenge this idea by showing that...". I don't think this is a challenge to the role of T in modulating more antisocial forms of behavior (e.g., aggression), but instead, this new evidence suggests that the role of T in more complex.

Response 1: We have rephrased this sentence accordingly, “Recent research [10–12], however, has revealed a more nuanced role of testosterone ...” see Page 3.

Questioni 2: p. 4 lines 22-24 "Based on the Social Status Hypothesis, we hypothesized that exogenous testosterone would magnify the effect of being watched on altruistic behavior". This is a sound hypothesis, but I wonder about the role of T when in the private condition (i.e., when not being watched). Shouldn't this promote more

antisocial/selfish behavior? Keeping more money for oneself would enhance one's status via increased resources, suggesting that perhaps T would increase selfish behavior when not being watched by others.

Response 2: This is a good point. We have now acknowledged it on Page 14.

“Third, in our task, one could speculate that keeping more money for oneself in the private condition might have been a way to achieve status through resource (i.e., money) acquisition. However, when we decomposed the interaction effect found in the main statistical model, we found no evidence that the donation rate in the private condition was reduced in the testosterone condition compared to the placebo condition ($b = 0.727$, $SE = 0.673$, $Z = 1.081$, $p = .28$). More studies are needed to address the boundary conditions under which testosterone promotes generous and selfish behaviour.”

Question 3: p. 8 line 5 "For those participants experiencing the public condition first...". I think you mean private condition first.

Response 3: We thank the reviewer for carefully reading our manuscript and catching this error, which has now been corrected.

Question 4: p. 9. Examination of the heat map (fig 2) suggests that there might be an interesting drug X observation X cost x benefit interaction. I realize that such a 4-way interaction would be a nightmare to model/interpret. However, after reporting the drug X observation interaction, is it not possible to split the analyses by drug condition, and model the observation X cost X benefit interaction? I suspect such an interaction would emerge for the T condition, whereby a greater probability of accepting the transfer occurs primarily in the high cost/high benefit condition.

Response 4: We thank the reviewer for this suggestion. We have now reported the three-way interaction between observation, cost, and benefit for testosterone and placebo

group separately in Table S1. The three-way interaction was significant under both the testosterone and placebo condition, and it was stronger for the placebo condition.

Question 5: p. line 15. Good - but it would be very helpful to know whether any of the individual difference variables interacted with the public vs. private manipulation and/or drug condition. This could easily be reported in the supplementary materials and discussed as "exploratory analyses". This suggestion is especially relevant given the work by Bird et al (2019) showing that effects of T on cooperation (public goods game) depend on context (fast vs. slow decisions) and personality (high vs. low risk personality traits) see: <https://www.nature.com/articles/s41386-018-0220-8?draft=marketing>

Response 5: We appreciate this suggestion from the reviewer. We have now tested the interactive effects between each personality trait and our independent variables. We have reported these results in Table S3.

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