Peer Community In
Health & Movement Sciences

Does aging affect implicit motor adaptation?

Rajiv Ranganathan *based on peer reviews by* ***Kevin Trewartha*** *and* ***Marit Ruitenberg***

Pauline Hermans, Koen Vandevoorde, Jean-Jacques Orban de Xivry (2023) Not fleeting but lasting: Limited influence of aging on implicit adaptative motor learning and its short-term retention. bioRxiv, ver. 2, peer-reviewed and recommended by Peer Community in Health and Movement Sciences. https://doi.org/10.1101/2023.08.30.555501

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Motor adaptation to environmental perturbations (such as visuomotor rotations and force fields) is thought to be achieved through the interaction of implicit and explicit processes [1]. However, the extent to which these processes are affected by aging is unclear, partly because of differences in experimental protocols. In this paper, Hermans et al. [2] address the question of whether the implicit component of learning is affected in older adults. Using a force-field adaptation paradigm, the authors examine implicit adaptation and spontaneous recovery in healthy young and older adults. Overall, the authors found that both total adaptation and implicit adaptation was not affected in older adults. They also found evidence that spontaneous recovery was associated with implicit adaptation, but was not affected in older adults. These results are noteworthy because they challenge some prior work in the field [3], but are also consistent with results from other experimental paradigms [4]. A main strength of the current paper is the rigor applied to testing this question. The authors provide robust, converging evidence from multiple analyses and statistical methods, and control for confounds both statistically and experimentally. Readers might want to note that this is a 'conceptual' replication of the previous study [3], and there are some potentially important differences in experimental details, which are clearly outlined. The sensitivity of the findings to such experimental parameters needs further testing. More broadly, these results highlight the need for greater understanding of how age differences observed in other motor learning tasks [5] are reflective of deficits in learning mechanisms.

References:

1. Taylor, J. A., & Ivry, R. B. (2011). Flexible cognitive strategies during motor learning. PLoS computational biology, 7(3), e1001096. https://doi.org/10.1371/journal.pcbi.1001096

2. Hermans, P., Vandevoorde, K., & Orban de Xivry, J. J. (2024). Not fleeting but lasting: Limited influence of aging on implicit adaptative motor learning and its short-term retention. bioRxiv, ver.2, peer-reviewed and recommended by PCI Health & Movement Sciences. https://doi.org/10.1101/2023.08.30.555501

3. Trewartha, K. M., Garcia, A., Wolpert, D. M., & Flanagan, J. R. (2014). Fast but fleeting: adaptive motor learning processes associated with aging and cognitive decline. The Journal of neuroscience : the official journal of the Society for Neuroscience, 34(40), 13411–13421. https://doi.org/10.1523/JNEUROSCI.1489-14.2014

4. Vandevoorde, K., & Orban de Xivry, J. J. (2019). Internal model recalibration does not deteriorate with age while motor adaptation does. Neurobiology of aging, 80, 138–153. https://doi.org/10.1016/j.neurobiolaging.2019.03.020

5. Voelcker-Rehage, C. (2008). Motor-skill learning in older adults—a review of studies on age-related differences. European review of aging and physical activity 5, 5–16. https://doi.org/10.1007/s11556-008-0030-9

Reviews

Evaluation round #2

Reviewed by Kevin Trewartha, 13 February 2024

Review of the revised article “Not fleeting but lasting: Limited influence of aging on implicit adaptative motor learning and its short-term retention” by Pauline Hermans, Koen Vandevoorde, and Jean-Jacques Orban de Xivry, submitted to PCI Health and Movement Science.

The authors have provided a nice revision of their paper. Again, I think this study is very well done, the findings are interesting and make a nice contribution to the literature, and the authors have adequately addressed the majority of my questions. I only have one more remaining constructive comment below:

I appreciate the authors’ making an effort to emphasize that this is a conceptual replication. I also share their view that such conceptual replications are important, despite the fact that such studies have limitations/weaknesses. I also appreciate the addition of a paragraph in the discussion to further emphasize the conceptual replication point. However, it is worth considering the claim that is made at the end of this paragraph. It assumes that an age difference in spontaneous recovery is a finding that is “likely dependent on the experimental conditions.” By that same logic, the finding of a lack of age difference in spontaneous recovery is likely dependent on experimental conditions. I argue that a better statement would emphasize the need for further research to understand the conditions under which there is, and is not an age difference in spontaneous recovery, and to further explore the implications for those observations for the view that spontaneous recovery specifically reflects implicit learning/memory processes.

Reviewed by Marit Ruitenberg, 07 February 2024

In my review of the previous version of this manuscript, I expressed my concerns regarding rationale behind the work, the specificity of the hypotheses, the description of the experimental task, and some of the analysis. These concerns have been resolved in the revised version of the manuscript and the revisions have helped to improve the quality and clarity of the work. I have no remaining comments.

Evaluation round #1

DOI or URL of the preprint: https://www.biorxiv.org/content/10.1101/2023.08.30.555501v1
Version of the preprint: 1

Authors' reply, 17 January 2024

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Decision by Rajiv Ranganathan, posted 30 October 2023, validated 31 October 2023

Not fleeting but lasting: Limited influence of aging on implicit adaptative motor learning and its short-term retention - Revision requested

Thank you for your submission titled "Not fleeting but lasting: Limited influence of aging on implicit adaptative motor learning and its short-term retention". The paper addresses the question of whether aging affects the implicit component of learning . In my own reading of the article (and echoed by the comments from the two reviewers), this a very well-done study with several strengths– the paper addresses an important question and uses a well-established approach to addressing the question. In addition, the methods and analysis are also rigorously done, and presentation of the results is transparent (with robustness checks also being provided).

However, the reviewers have raised a few concerns that need addressing before I can provide a recommendation. As you will see, both reviewers have provided thoughtful reviews and suggestions – so I hope the authors will address these concerns. Both reviewers raise important theoretical and methodological clarifications that will help improve the clarity of the manuscript. I will simply highlight what I see as a main concern here (mentioned by Reviewer 2).

The main concern is the framing of the paper as a conceptual replication. As highlighted in several discussions on the replication crisis (notably by Chambers in "The 7 Deadly Sins of Psychology"), unlike a direct replication, the idea of a "conceptual" replication is subjective and often difficult to get agreement on since it is difficult to determine apriori if the parameters that were changed from the original study are critical to the original result (While the arguments against conceptual replication are typically used when a conceptual replication 'agrees' with the original result, it is probably fair to say that they also apply when the conceptual replication 'fails', as in this case). Thus, while the current study seems to a fair and rigorous test of the original question (with a section in the Discussion highlighting differences from the original study), the framing at several points in the paper (from the Abstract to the conclusion) often blurs this difference between a conceptual and a direct replication (e.g., "We failed to replicate…"). This could potentially be misleading as it could lead readers to think that this was a direct replication failure.

I would therefore suggest that 'conceptual replication' framing needs some re-consideration. One possibility is that the authors could choose to address this as a study of the research question on its own (while of course still comparing the results from the original study). However, if the authors want to retain this framing of a conceptual replication, it might help to be more transparent right from the outset that conceptual replications have some weaknesses (and make sure that the terms such as 'failed to replicate' are not used ambiguously in the manuscript)

A minor concern is that the data file in the repository seems to be one big MATLAB file which can only be used with the author's code as far as I could tell (but this code is provided). However, it would be helpful to have the deposited dataset be "independently readable" (i.e., a datafile accompanied by a codebook that explains what these variables are and how they are organized) so that a potential reader could independently use the dataset without having to rely on the author's code.

Reviewed by Kevin Trewartha, 12 October 2023

Download the review

Reviewed by Marit Ruitenberg, 04 October 2023

The manuscript presents a comprehensive report on a behavioral study that investigates the effect of age on the contribution of implicit processes to motor adaptation and spontaneous recovery. The introduction presents relevant background information and the data-analysis approach via both frequentist and Bayesian models is an asset to the work. I also appreciate that the authors present individual data points in the figures and I believe that the discussion offers a sound, integrative interpretation of the findings. At the same time, I have several requests/questions related to clarification of the rationale behind the work, the specificity of the hypotheses, the description of the experimental task, and some of the analysis choices. I will provide more detailed comments below, which I hope will be helpful towards revising the work.

1. The introduction states that it currently is unknown whether age affects the implicit component of motor adaptation in a force-field paradigm. It would be helpful for readers if the authors could explain why it would be relevant/important to find an answer to this question. What is fundamentally different about motor adaptation in a force field versus visuomotor rotation paradigm that warrants the investigation performed in the current study? To be clear: I do agree that this is important, but just think it should be clarified more explicitly why this is the case.

2. I found the description of the timescales of different processes involved in spontaneous recovery relatively difficult to follow, and am afraid I was lost at the sentence "…which is not washed out by the few deadaptation trials whilst also rapidly forgetting". The sentence seems to involve different theoretical constructs and grammatical structures. Would it be possible to present this in a different manner, such that the contributions of slow and fast processes are addressed separately for example?

3. When presenting the hypotheses, please clarify the directionality of the expected group differences and associations. I also recommend adding the research question / hypothesis related to working memory capacity here, as that construct is now only introduced in the methods section yet it forms an important element in the results and discussion.

4. Have the authors performed a sample size calculation or could they provide another type of justification for including 21-28 participants per group in their experiment?

5. What were the exclusion criteria for participation related to the general health and consumption habits questionnaires that were used during screening?

6. I have several questions about the description of the experimental paradigm;

   (a) My assumption would be that participants could not just move the handle in the horizontal direction, but also diagonal and forward/backward, as otherwise they would be unable to reach each of the target locations. I therefore wonder is perhaps the statement in line 93 is incorrect? Or do the authors mean to say that the handle moves in 2D?

   (b) Did the robotic handle return to the starting point after each trial, or did different trial start out from different hand/arm positions?

   (c) To what extent can the uncued trials really be considered as uncued? Unless I misunderstood the description of the task (in which case, please revise the text as other readers may understand the text similarly), it seems that the white color of the cursor still provides information to participants about what type of trial is to come.

(d) With respect to the error-clamp phase, I think it would be helpful to briefly explain what these trials are and whether any feedback was provided. I also strongly recommend to clarify in the text that these trials were not presented on all target locations (currently this is only mentioned in the figure caption).

(e) I am not quite sure I understand what it means that there was a channel and the hand was guided through it in the error-clamp phase. Did a physical channel appear in the apparatus?
It would be helpful to add some text-info on the phases (e.g., baseline, washout) in Figure 1, which is currently done for the error-clamp phase but not others.

7. Regarding the WM task, it would be helpful to clarify early on that it concerns a visual WM measure. My suggestion would be to describe both the task and the outcome measure in a separate WM paragraph, rather than as part of the experimental adaptation paradigm.

8. I suggest renaming the data analysis paragraph to 'data processing and analysis'. In addition, I think the authors could consider using same order of information as in the task description; this will make the section much easier to follow.

9. Given that there are quite a larger number of analyses that are being performed, it would be helpful to clarify how they link to the hypotheses. This will also allow for a more concise, integrated presentation (instead of repeatedly saying 'the same was done for…'). Could the authors also explain what levels are included in their multilevel correlation? I assume it includes age to account for differences between groups, but this is currently not described.

10. I missed a description of the WM correlation analyses, and would like to suggest to include age group in the model as well. Work by Seidler has shown that the association between adaptation and WM capacity is different for younger and older adults. It therefore seems reasonable to analyze the younger and older groups separately and/or include group as a factor. Not doing so could potentially have obscured any group-specific results, and the data patterns in Fig. 6 seem to possibly support this notion (though I simply base this on visual inspection, so am not sure that statistical results will concur).

11. The use of Bayesian in addition to frequentist statistics to study spontaneous recovery is an asset to the study (although the rationale behind and difference between analysis 4 and 7 were not fully clear to me). The results of the Bayesian analyses do not strongly support the conclusions in the way that PCI defines this (i.e., BF>20), yet I feel this is adequately addressed in the discussion section where the authors acknowledge that the range of effects even includes the possibility of an opposite age pattern). To further support the presented findings, the authors could also apply a Bayesian approach to analyses that go beyond spontaneous recovery, such as the age effect on adaptation and the association between adaptation and WM capacity. This would subsequently allow for interpretations such as the one currently presented in line 13 of the abstract ("both groups adapted equally well" – assuming this is indeed what the BF will support).

12. When looking at Figure 2A, it seems that there was no complete washout as the deviation does not return to zero. To what extent could this have affected the (interpretation of) the findings? It seems that this is an important point for the discussion section.

13. Line 290 may give the impression that data sets from a prior study and the present study were combined. This is a bit misleading, so I suggest to rephrase this.

14. In the discussion, the authors could address practical/clinical implications of their findings (e.g., with regards to physical therapy/rehabilitation after a fall). In addition, I recommend discussing the generalizability to longer-term memory (i.e., savings), or other forms of adaptation (e.g., rotated feedback in the manual domain, but also potential extensions to the locomotor domain).

15. Lines 447-449; It would be helpful if the authors could explain why the inter-subject variability difference between younger and older adults is a limitation. How does it affect the (boundaries of) interpretation of the present findings? I would also like to read more about how they envisage this issue being tackled. Do the authors mean that researchers should look for more homogeneous older adult groups? Or that specific methodological/statistical approaches should be developed to

16. Throughout the manuscript there are several instances were small corrections or additions to the text would be very helpful for readers. I list some examples from the introduction section here, but encourage the authors to check for other similar issues in the remainder of the manuscript;

    (a) Lines 23 and 25; I suggest changing the phrasing of 'thanks to' to 'via' or 'through'.

    (b) Line 27; Could the authors please clarify what it is that is being updated? I think they may be referring to motor representations, but this is currently up to the reader to infer and would be easier to understand if it was made explicit.

    (c) Line 36; What do the two sets of references mean?

    (d) Line 37; This should read 'suggests'.

    (e) Line 44; Please explain what the little difference refers to; I think it refers to adaptation performance between younger and older age groups, but this should be clarified.

    (f) Line 53; 'which IS hidden'

    (g) Line 67; I'm not sure how three things can be contradictory.

    (h) Line 73; Start the sentence with 'As it is known…'