Reply to Walker and Stickgold: Proposed boundary conditions on memory reconsolidation will require empirical verification

Tom E. Hardwicke & David R. Shanks

University College London

Author note

Tom E. Hardwicke & David R. Shanks, Department of Experimental Psychology, University College London.

All data, analysis code, and experimental programs pertaining to this article have been made publically available on the Open Science Framework (https://osf.io/gpeq4/).

Correspondence concerning this article should be addressed to Tom E. Hardwicke, Department of Experimental Psychology, University College London, 26 Bedford Way, London, UK, WC1H 0AP. E-mail: t.hardwicke.12@ucl.ac.uk

Broadly speaking, non-replications of the kind we reported (1) can occur for three reasons: (a) the original finding was a false positive; (b) the replication was a false negative; or (c) some unanticipated variable(s) moderates the effect. The original authors (from herein 'W&S', ref. 2) have proposed several potential moderators (3).

We welcome such discussion, however we should note that both parties are now 'hypothesizing after the results are known' (4), and are therefore in an exploratory ('hypothesis-generating'), rather than confirmatory ('hypothesis-testing') phase of scientific inquiry (5). Any post-hoc conjectures will require empirical verification.

W&S note that participant age and session time had a larger range in the replications. As they previously raised these points during the review process, we have already addressed them in our article (ref. 1, SI Results). In brief, reconsolidation scores had no appreciable relationship with either session time or age.

W&S refer to the subtle modification to the instructions of Experiments 3 and 4, but their line of reasoning is a little hard to decipher: if this was a critical moderator then why were reconsolidation effects not observed in Experiments 1 and 2 which used instructions identical to the original study? The instructions were changed in Experiments 3 and 4 precisely because we were attempting to match the error rates reported in the original study.

Similarly, W&S note that in Experiment 1, overnight improvements in speed were smaller than in Experiments 2-4. Again, if this were a critical moderator, reconsolidation effects would have emerged in Experiments 2-4.

W&S refer to "two independent replications" of the original finding (6, 7). We briefly discussed this set of studies (6, 8) in our article (1) and we do not believe that W&S's characterization is accurate. In all studies (6-8) there was a small Day 2 – Day 3 performance *improvement*, whereas the original finding was a performance *decrement*: the effects are in opposite directions. These studies were interpreted as 'blocked offline gains' because the improvements were smaller than in a no-intervention control group. Not only is this a qualitatively different effect, it is rather tenuous evidence for reconsolidation: (a) there was no 'no-reactivation' control condition; (b) the intervention (TMS rather than new learning) was delivered during, rather than after reactivation; and (c) such 'offline gains' can often be driven by

procedural confounds (9).

Finally, W&S note that "almost two-dozen human studies and over 900 animal studies have reported reconsolidation". We are concerned that many of these studies do not employ adequate controls, have not been independently replicated, and do not test retrieval failure explanations (see ref. 1 discussion, also see ref. 10).

To conclude, we disagree that the moderators proposed by W&S can be viewed as 'boundary conditions' on reconsolidation theory because they (a) are at present only post-hoc conjectures; and (b) do not provide a compelling account of the extant data. Nevertheless, this discussion has generated a number of testable hypotheses that can be empirically verified with new data.

References

1. Hardwicke TE, Taqi M, Shanks DR (2016) Postretrieval new learning does not reliably induce human memory updating via reconsolidation. *Proc Natl Acad Sci USA* 113(19):5206–5211.

2. Walker MP, Brakefield T, Hobson JA, Stickgold R (2003) Dissociable stages of human memory consolidation and reconsolidation. *Nature* 425(6958):616–620.

3. Walker, M. P. & Stickgold, R. (2016). Understanding the boundary conditions of memory reconsolidation. *Proc Natl Acad Sci USA*

4. Kerr NL (1998) HARKing: Hypothesizing after the results are known. *Pers Soc Psychol Rev* 2(3):196–217.

5. Wagenmakers E-J, Wetzels R, Borsboom D, van der Maas HLJ, Kievit RA (2012) An agenda for purely confirmatory research. *Perspect Psychol Sci* 7(6):632–638.

6. Censor N, Dimyan MA, Cohen LG (2010) Modification of existing human motor memories is enabled by primary cortical processing during memory reactivation. *Curr Biol* 20(17):1545–1549.

7. Censor N, Dayan E, Cohen LG (2014) Cortico-subcortical neuronal circuitry associated with reconsolidation of human procedural memories. *Cortex* 58:281–288.

8. Censor, N., Horovitz, S. G., & Cohen, L. G. (2014). Interference with existing memories alters offline intrinsic functional brain connectivity. *Neuron*, *81*(1), 69–76.

9. Rickard TC, Cai DJ, Rieth CA, Jones J, Ard MC (2008) Sleep does not enhance motor sequence learning. *J. Exp. Psychol.-Learn. Mem. Cogn.* 34(4):834–842.

10. Riccio DC, Millin PM, Bogart AR (2006) Reconsolidation: A brief history, a retrieval view, and some recent issues. *Learn Mem* 13(5):536–544.