Title: Enhancement of motor skill memory through reconsolidation

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Recent work on memory reconsolidation has shown that a previously consolidated motor skill memory can be weakened following reactivation and subsequent exposure to an interfering intervention. Since other forms of memory can be enhanced through reconsolidation, we wondered if motor skill memory could be strengthened following reactivation and exposure to a different type of intervention. We hypothesized that following reactivation, exposure to an intervention that increased performance error, but maintained an endogenous credit assignment of the errors, could be used to enhance the memory of a previously consolidated skill.

Participants learned a thumb-index finger pinch force task where force mapped logarithmically to lateral cursor displacement (Figure 1). Subjects moved the cursor sequentially to a set of 5 targets. Participants learned this sequential visual isometric pinch force task (SVIPT) over 3 sessions (4 blocks of 30 trials each). Following an initial training session (0 hr), participants returned after a 6-hour delay, and the following day (24 hr). Memory for this motor skill has been shown to consolidate within a 6-hour period. Participants reactivated their memory for the consolidated motor skill when they returned after the 6-hour delay. During this second session, they either continued on the previously learned function (FIX), or were exposed to a "variable trial intervention" (VAR). During VAR, participants responded to the intermixed presentation of 6 new logarithmic functions, as well as the original function (Figure 1B). These new functions were fit using cursor endpoint variance (+/- 3SD, 1SD increment) to each of the 5 targets derived from an independent dataset. This intervention could not be distinguished from the original function. The effect of intervention was measured as the difference in learning (speed/accuracy composite, Δ skill), between the first block during session 3 on the following day (24hr) from the last block during session 1 (0hr).

Exposure to the variable skill task after reactivation led to greater learning (VAR vs. FIX: $t = 2.52$; $p = 0.027$) despite the lack of any performance improvement during the intervention session (Figure 2A). On the other hand, the FIX group showed little benefit from the intervention when compared to a control group (noINT) that did not receive additional training at 6 hours (FIX vs. noINT: $t = 0.55$; $p = 0.59$). This suggests that the variable intervention recruits learning mechanisms that are otherwise down regulated during repetitive practice. Additional controls confirmed that variable intervention enhancement was due to the reactivation of a consolidated memory of the initial skill (Figure 2B), and not simply an effect due to variable practice (Figure 2C). Moreover, how skillful participants responded to the intervention determined the magnitude of offline learning. In particular, those with high accuracy following large fluctuations in trial-to-trial mapping had greater skill strengthening ($r = -0.63$, $p = 0.037$, Figure 3). These findings provide evidence that reconsolidation of motor skill memory can be constructive. Subtle variability appears to provide a powerful means to protect and further enhance previously consolidated memory, likely through the continued engagement of error correction mechanisms that operate in parallel with plasticity-like processes.

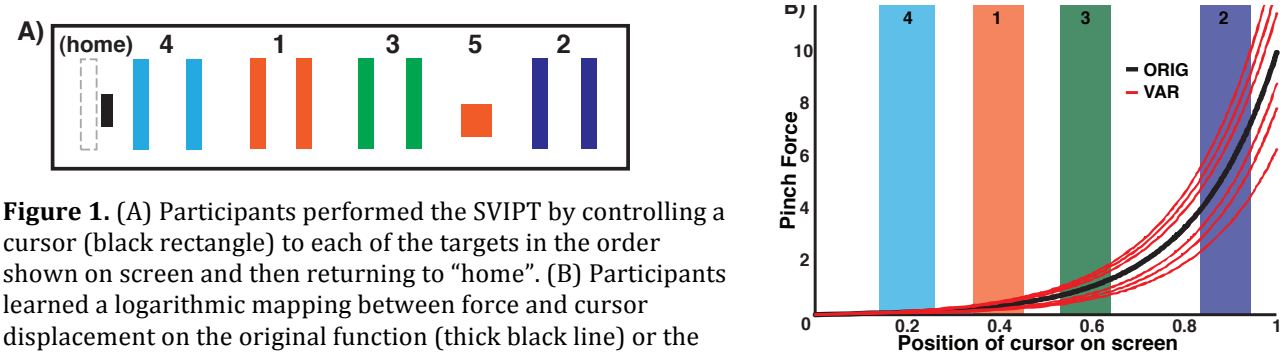

Figure 1. (A) Participants performed the SVIPT by controlling a cursor (black rectangle) to each of the targets in the order shown on screen and then returning to "home". (B) Participants learned a logarithmic mapping between force and cursor displacement on the original function (thick black line) or the variable intervention (thin red and black lines).

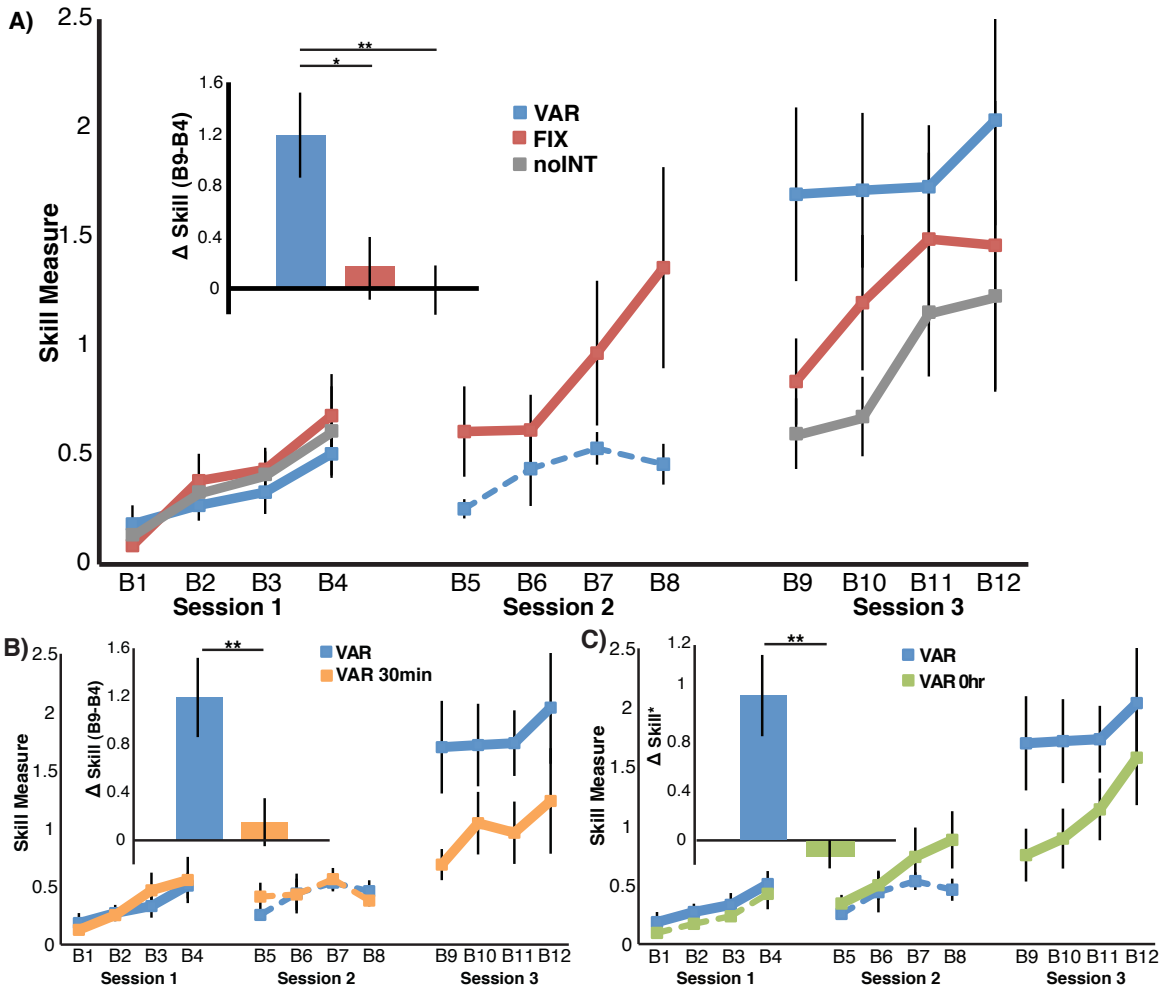

Figure 2. (A) Learning was strengthened after exposure to the variable intervention (VAR) during Session 2. The Δ skill is stronger for VAR relative to a group that received extra practice on the original function (FIX) and those that did not practice (noINT) during Session 2. (B) Strengthening (Δ skill) was not observed if participants were exposed to the variable intervention 30 minutes after learning the original function (VAR 30min), prior to the consolidation of the original function. (C) Exposure to the variable intervention during Session 1 (VAR-0hr) did not strengthen original function performance during Session 2. Hence, there is no general enhancement of learning without a prior representation of the original function. *The Δ skill for VAR-0hr was calculated as B5-B4. Error bars show SEM.

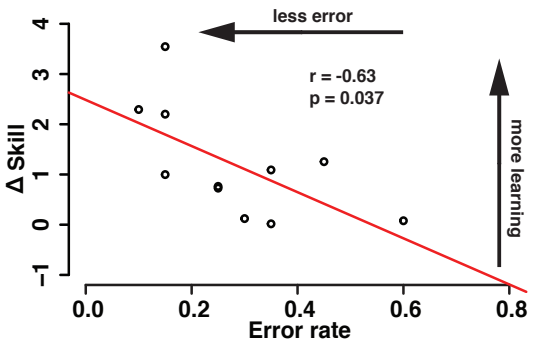

Figure 3. Memory strengthening (Δ skill) was correlated with participant's accuracy on those trials that followed a large trial-by-trial mapping change during the variable intervention.