**Varied Rotations Articles (random & Pseudorandom)**

Facilitation of learning induced by both random and gradual visuomotor task variation

Turnham et al 2012

**Intro**

* “Learning to learn” has been demonstrated for cognitive tasks in animals and humans and sensorimotor tasks (Welch et al. 1993; Roller et al. 2001; Seidler 2004, 2007; Cohen et al. 2005; Seidler 2007; Braun et al. 2009a,b; Mulavara et al. 2009).
  + Many studies use a random training sequence so that performance during training is poor but, there is greater retention and better transfer. (Battig 1966, 1972, 1979; Shea and Morgan 1979; Magill and Hall 1990; Brady 2008; Schweighofer et al. 2011).
    - So this is sequence learning, not so much rotation training (Braun et al 2009.
    - The benefits could be due to structural learning of how to tackle the sequence or motor activity.
* The two-rate model by smith is great for explaining:
  + Savings, anterograde interference, spontaneous recovery & rapid unlearning
  + However, this model cannot capture more complex processes of meta-learning that are likely to require changes to the learning and forgetting rates (Zarahn et al. 2008), and forgetting rates have been shown to be modulated by prior experience (Huang and Shadmehr 2009).

**Methods**

* Rotation changed every 16 trials, rotation was either:
  + Randomly chosen from 100 angles between -60 & 60.
  + Gradual 1 & 2, started @ 0 and ended at 0 went to either -60 or + 60 first and then back
  + Aligned group
* Washout session with aligned feedback
* Three blocks of +30, -30 & +30 rotations.
  + This was used to measure interference and time taken to initiate movements
* Our primary measure of the rate of adaptation is the drop in error over the first ten trials, as a proportion of the error on the first trial. This measure avoids confounding the rate of adaptation to the current rotation with the aftereffect of the previously learned rotation and was calculated from the exponential-based functions shown in the middle row of Fig. 6.

**Results**

* During test phases:
  + No one fully adapted to the rotations (-30 to 30).
  + Random & gradual group showed a lot of variability some people learned and others didn’t, whereas everyone learned in control.
* Fast retention rate was higher for gradual and random groups than the control group, with retention being the highest in the gradual group.
* The random group initiated their movements faster than the other groups.

**Discussion**

* The groups experienced 3,6 and 20 degree errors during the training phase but showed similar amounts of compensation during the testing phase indicating that regardless of the size of the error experienced learning occurred the same.
* Generalization curves were similar for both gradual and random groups
* The participants were required to move out fast and that should have limited access to cognitive strategies. They also used test rotations sizes of 30 degrees as those are smaller and should be less explicit.
* Our approach of analyzing the speed of adaptation (Sing and Smith 2010; Krakauer 2009; Zarahn et al. 2008; Smith et al. 2006; Kojima et al. 2004; Miall et al. 2004; Bock et al. 2001; Abeele and Bock 2001), rather than averaging errors over the first few or all the trials of exposure to a task (Cunningham 1989; Brashers-Krug et al. 1996; Shadmehr and Brashers-Krug 1997; Imamizu et al. 2007; Braun et al. 2009b), allows us to separate the aftereffect of previous learning from the rate of adaptation.
* We find that in all subject groups the rate of adaptation to the ⫺30° test rotation is at least as great as that to the preceding ⫹30° rotation, and the rate of adaptation on the second ⫹30° block is at least as great as that on the first ⫹30° block. These results show that anterograde interference between the opposing rotations consists only of an aftereffect rather than a reduction in learning rate.
* Zarahn et al. (2008) showed that linear state-space models of adaptation (e.g., Smith et al. 2006) cannot explain processes of meta-learning and argued that variable-rate adaptive processes are necessary to account for such phenomena. More specifically, Huang and Shadmehr (2009) showed that gradual introduction of a dynamic perturbation increased the retention factor of adaptive processes later in the experiment and that rapid introduction of a perturbation reduced the retention factor.
* With fits to individual subjects, we find that the learning rate of the fast process is increased considerably by both random and gradual learning.
* In the future, it will be interesting to develop variable rate models that can capture meta-learning pro- cesses as reported in our study and to fit them to trial-by-trial movement data.
* These differences between subject groups suggest that learning rates are adapted through experience as part of meta-learning processes that can depend on previous errors, task variability, mapping uncertainty, and structural similarity between tasks. While the way in which errors lead to changes in the internal state are well understood, future studies will need to understand how different features of experience change the learning rates and retention parameters of the processes underlying learning.