Dissociation of neural substrates for motor ~~planning~~ Learning and execution in learning multiple visuomotor mappings

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Introduction

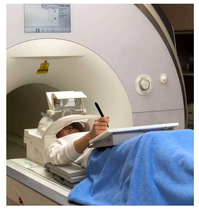
- Previous behavioral studies show that humans can simultaneously adapt movements to multiple visuomotor mappings after extensive practice [1, 2].
- However, in most motor adaptation tasks, learning involves altered movement execution (direction), which is not dissociated from learning.
- We designed a fast event-related fMRI experiment to dissociate motor learning from execution and investigated how they are represented in activity patterns.

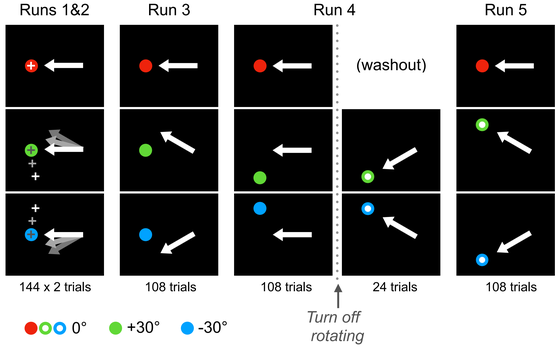
Research Questions

- How are motor learning and execution separately represented in the brain during motor adaptation of multiple tasks?
- How are motor learning and interference are represented as multi-voxel activity patterns in the brain?

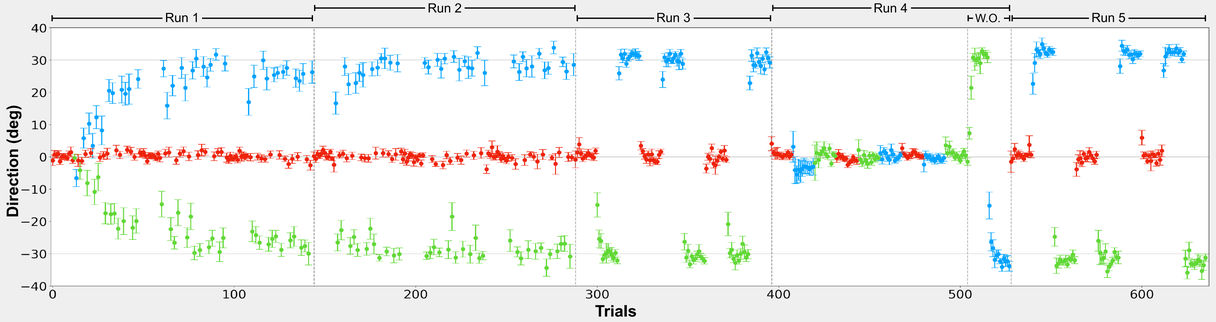
Experimental Design

- 33 young healthy right-handed participants (18 females, 15 males)
- 5 runs of motor adaptation tasks performed (approx. 1 hours)
  - **Task**: hitting a colored target using a MR-compatible tablet
  - **Runs 1 & 2**: 3 alternating blocks of (i) 12 **control** trials and (ii) 36 pseudorandom trials to adapt to **different rotations (R), same position (P)**
  - **Run 3**: 12 trials, 9 blocks to adapt to **different R, same P**
  - **Run 4**: (i) 12 trials, 9 blocks to adapt to **different R, different P,** (ii) 12 trials, 2 blocks of washout, **without rotation perturbation**
  - **Run 5**: 12 trials, 9 blocks to move to **same R, different P**





Behavioral Results of Multiple Visuomotor Mapping

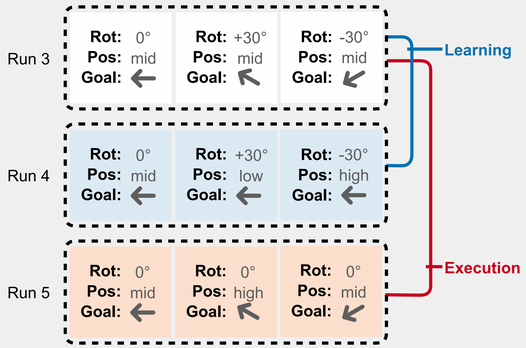


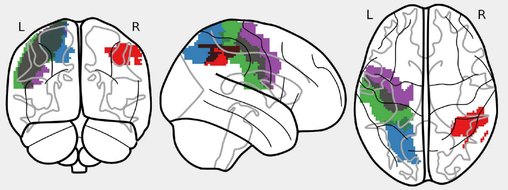
- Mean hand directions across trials from 33 participants
  - **Colors**: contextual cues for different visuomotor mappings (counterbalanced across subjects)
  - **Error bar**: standard error of the mean

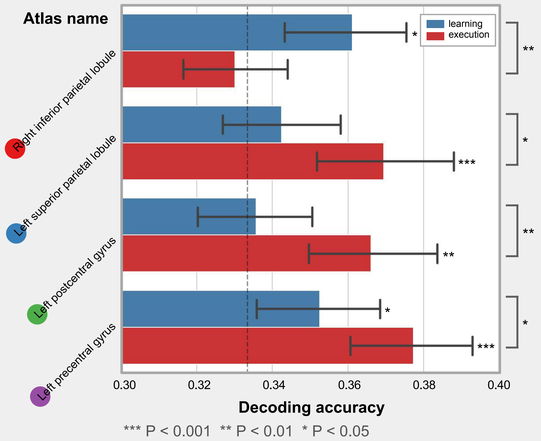
Motor Learning and Motor Execution Can Be Dissociated

- **Classes**
  - Learning: predicted rotation angles
  - Execution: actual hand movement angles
- **ROI Selection**
  - GLM analysis modeling target onsets in runs 1 and 2
  - Task-responsive voxels identified by GLM (uncorrected $p < 0.001$) in each ROI from AAL atlas
- **MVPA**
  - With Linear Support Vector Classifier (SVC) in each ROI

Cross Classification



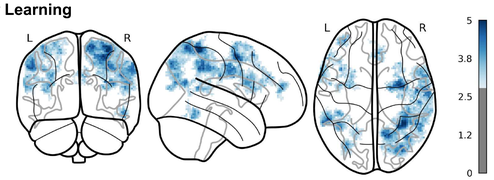




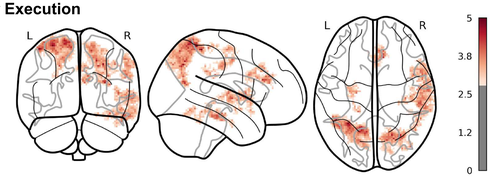
Localization of Learning and Execution

- **Searchlight analysis**
  - With Gaussian Naïve Bayes (GNB) classifier in radius 8mm
  - Uncorrected $p > 0.005$ and cluster size > 150 voxels
  - Possible lateralization

Motor Learning



Motor Execution



Discussion

- Using fMRI, we have successfully dissociated brain regions involved in motor learning and execution while learning multiple visuomotor mappings.
- Motor learning was decoded significantly higher in right inferior parietal region.
- Motor execution was decoded significantly higher in left superior parietal region and left M1, S1 than motor learning.
- Potential laterality [3] and dissociated roles of superior vs inferior parietal regions [4].
- We will further investigate how learning and interference are represented in activity patterns, using fully trained runs 3, 4 and 5 to predict learning and interference in runs 1 and 2.

References

[1] Ogawa, K. and Imamizu, H. "Human sensorimotor cortex represents conflicting visuomotor mappings." *J Neurosci,* 2013
[2] Kim, S. et al. "Neural substrates related to motor memory with multiple timescales in sensorimotor adaptation." *PLoS biology*, 2015
[3] Serrien D. J. et al, "Dynamics of hemispheric specialization and integration in the context of motor control." *Nat Rev Neurosci*, 2018
[4] Imamizu, H. Kawato, M. "Neural correlates of predictive and postdictive switching mechanisms for internal models." *J Neurosci,* 2008

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