Research on Learning & Memory with Neuromodulation in CLMN lab

Presented by
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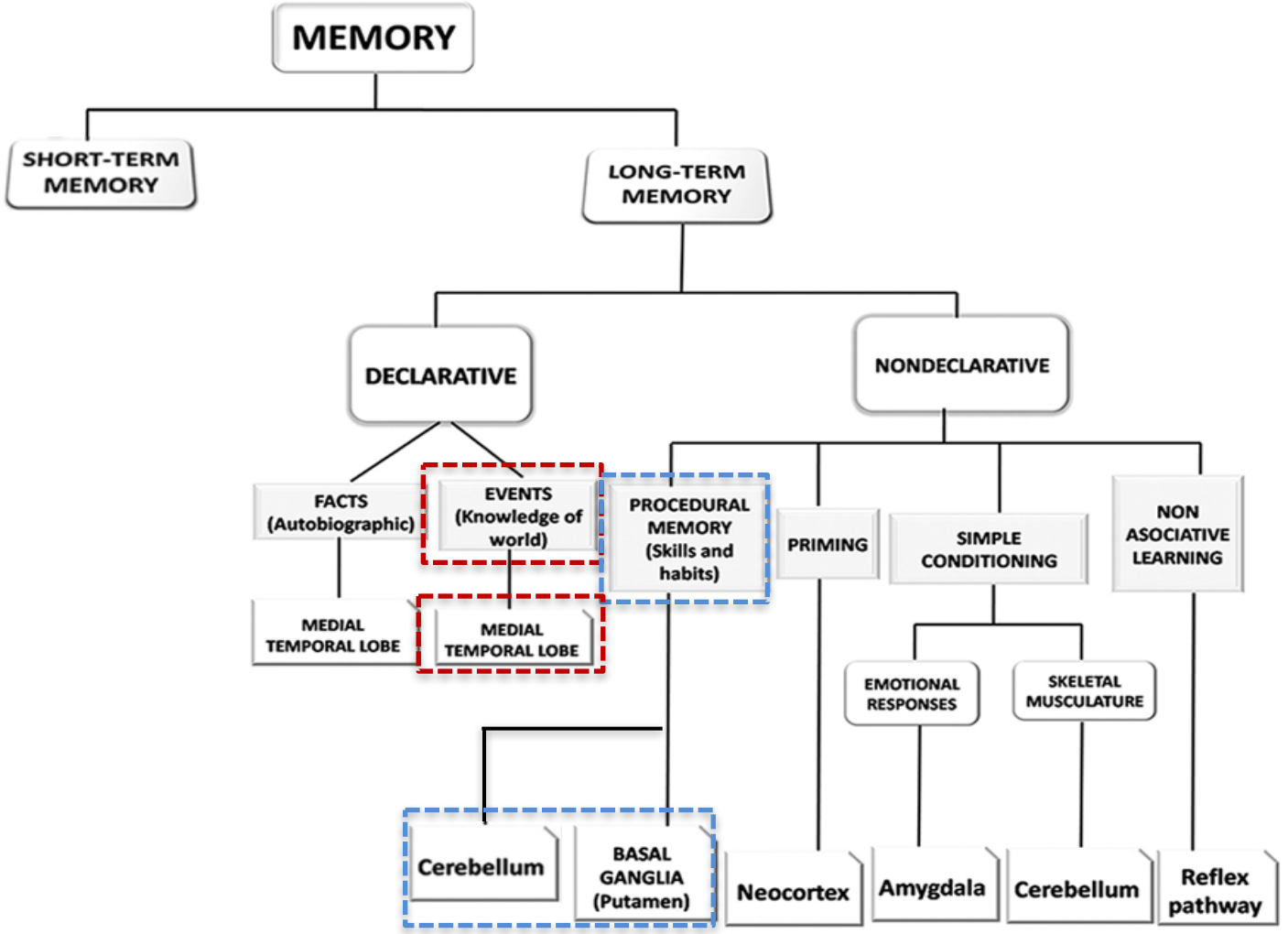
http://clmnlab.com

SUNG KYUN KWAN UNIVERSITY
Institute for Basic Science
Center for Neuroscience Imaging Research

Taxonomy of biological memory



Why motor Learning?

Our life is a continuum of motor learning

Learning new motor skills



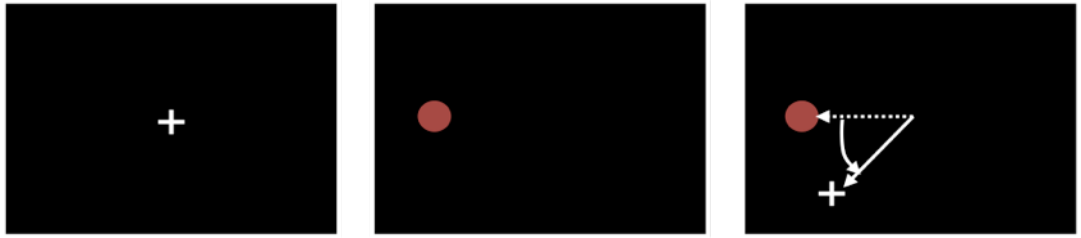

Adapting to changes

Regaining lost motor skills

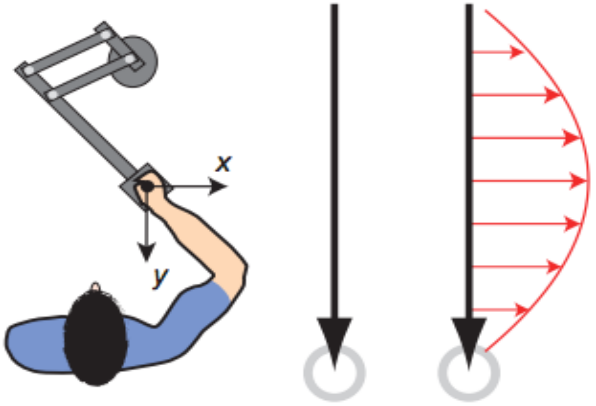
Two types of motor learning

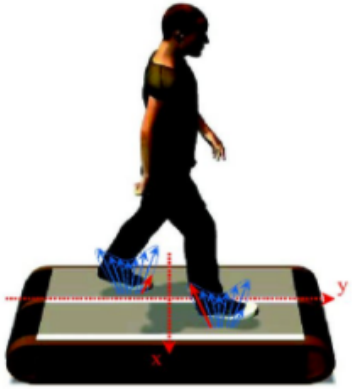
1. Motor adaptation

(1) visuomotor adaptation (kinematics)

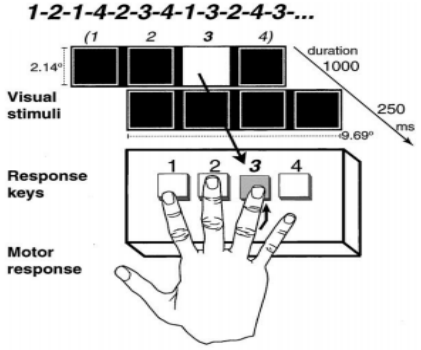


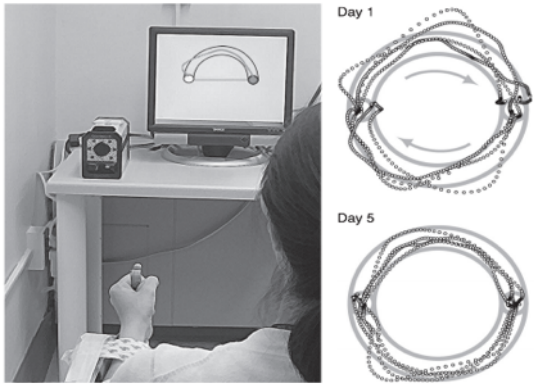
(2) force-field adaptation (dynamics)





2. Motor skill learning





Advantage of motor learning research:

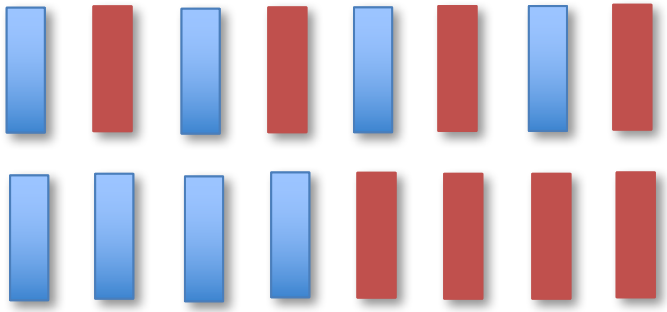
- ✓ Easy to quantify the amount of learning
- ✓ Possible to measure progress of learning
- ✓ Theoretical & computational approaches with models are encouraged

But, within-subject experiment design is difficult

Effects of task schedule on motor learning

Interference between tasks

- Contextual interference effect

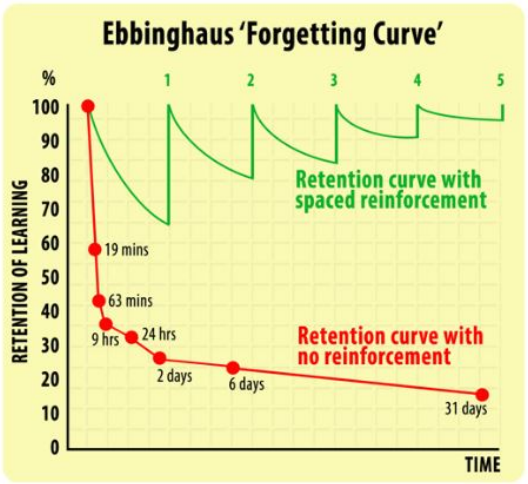


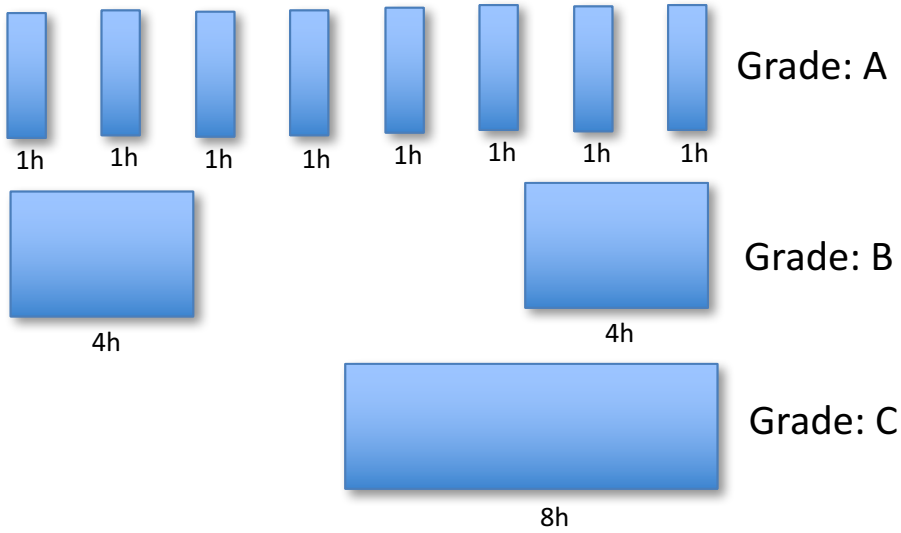
Grade: A

Grade: B

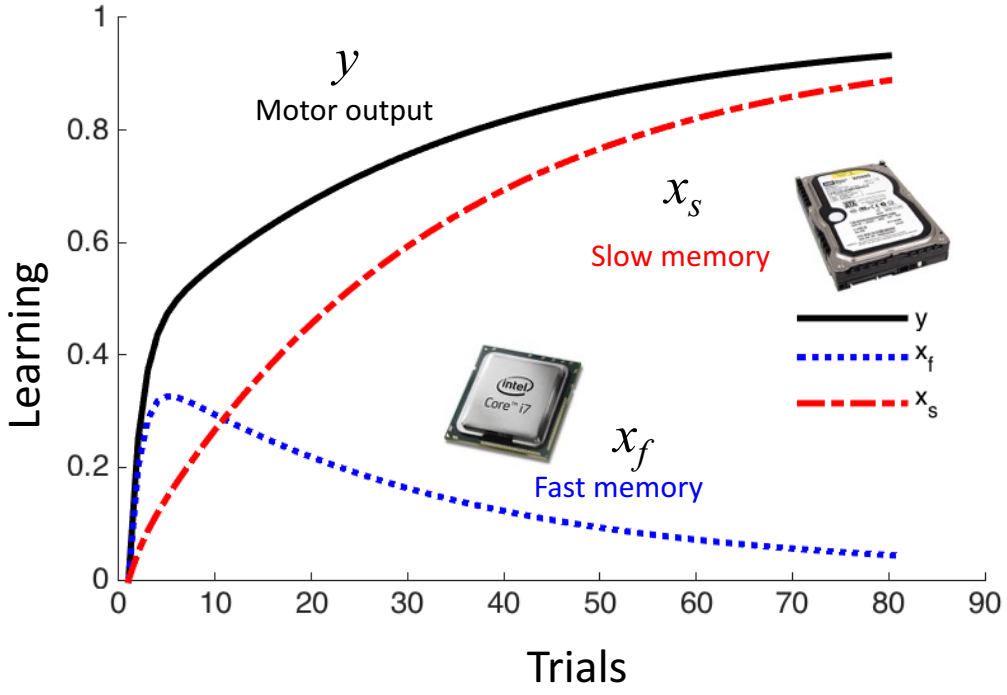
Time decay of memory

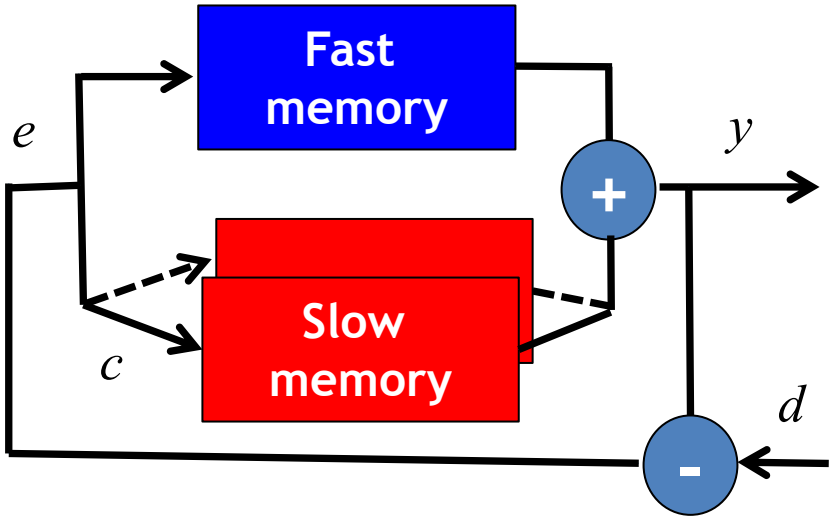
- Spacing effect





A computational model of motor learning & memory





$$y(n+1) = x_f(n+1) + x_s(n+1)$$

Fast memory $$x_f(n+1) = x_f(n)e^{-T(n)/\tau_f} + \beta_f e(n)$$

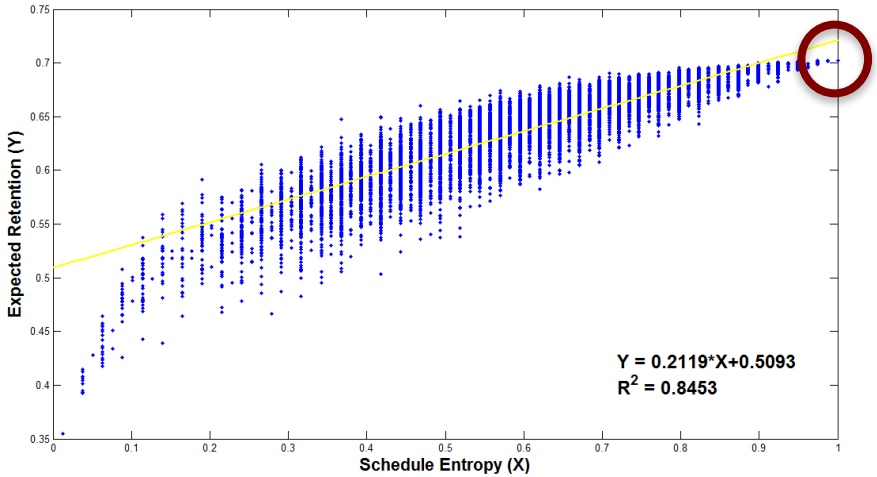
Slow Memory $$x_s(n+1) = x_s(n)e^{-T(n)/\tau_s} + \beta_s e(n)\cdot c(n)$$

Forgetting Learning

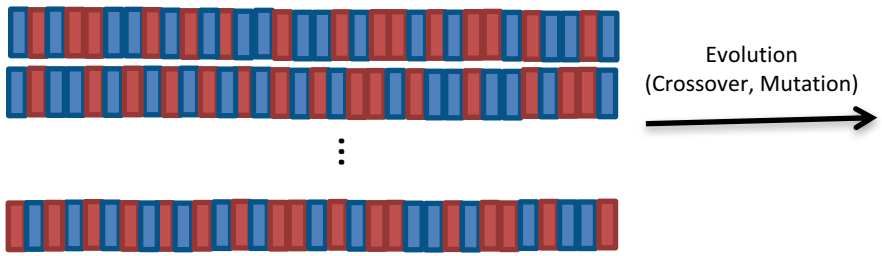
In search of optimal learning schedule

Best schedules for both two tasks?

$2^{31} \approx 2 \times 10^9$ possible schedules!

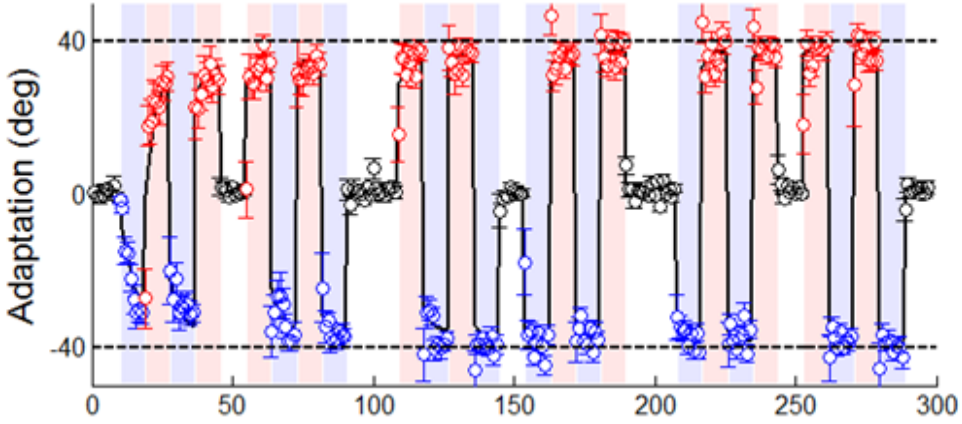


Model-based optimal schedule searching Algorithm (e.g., Genetic algorithm)



JY Lee, Y Oh, **SS Kim,** R Scheidt, N Scweighofer, *Neural Comput*, 2016

Neural substrates of memories with multiple time scales (modeling)



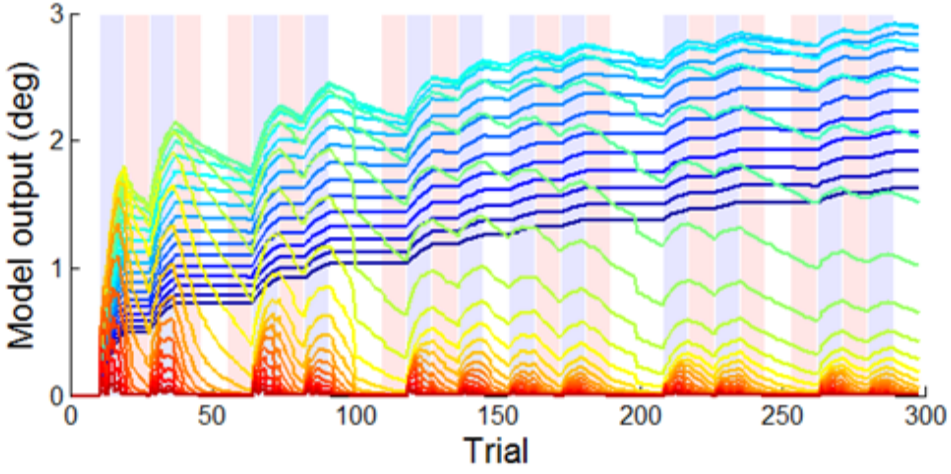
$$y(n) = \sum_{k=1}^{30} \mathbf{x}_k(n)^T \mathbf{c}(n)$$

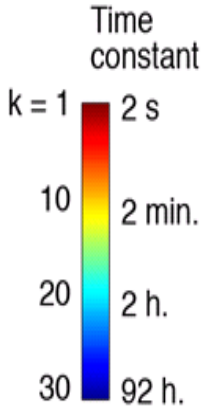
$$\mathbf{x}_k(n+1) = \mathbf{x}_k(n)\exp(-T(n)/\tau_k) + \beta_k \cdot e(n) \cdot \mathbf{c}(n)$$

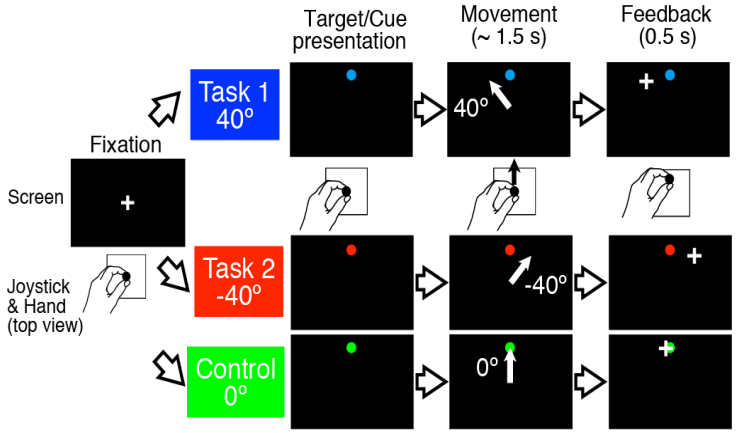
Forgetting Learning

$$\beta_k = \frac{r}{\tau_k^q}(k = 1,..,30)$$

$$\mathrm{RMSE} = 4.96^{\circ}, \mathrm{R}^2 = 0.981$$

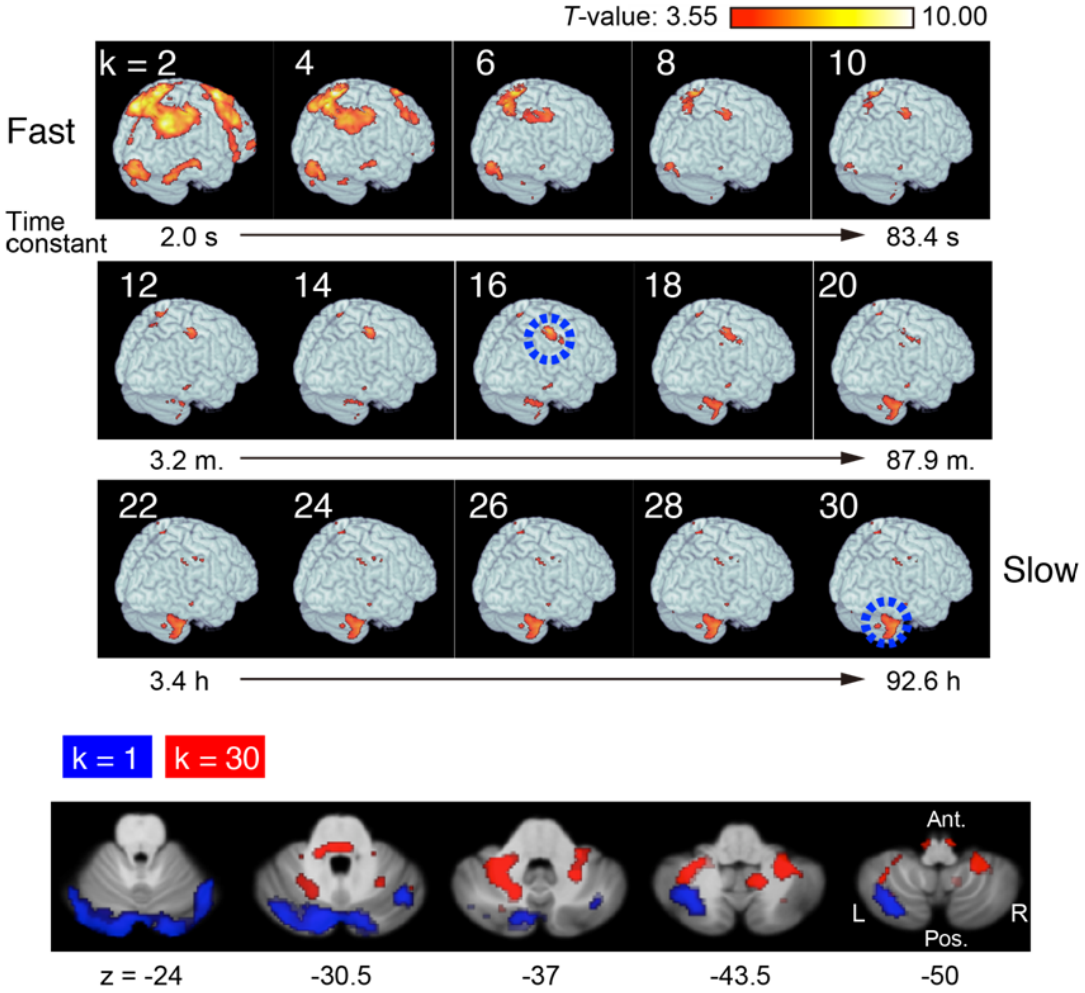






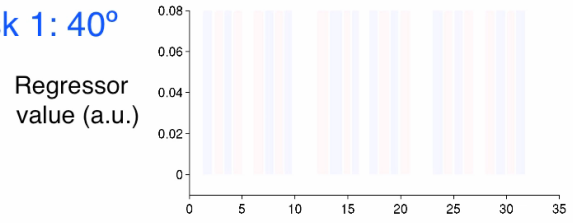
S Kim, K Ogawa, J Lv, N Scweighofer, H Imamizu, *PLoS Biology*, 2015

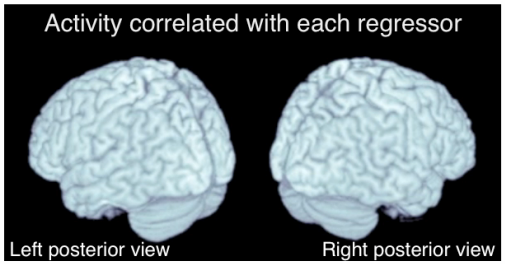
Neural substrates of memories with multiple time scales (fMRI results)



Regression results

- Task 1: 40°

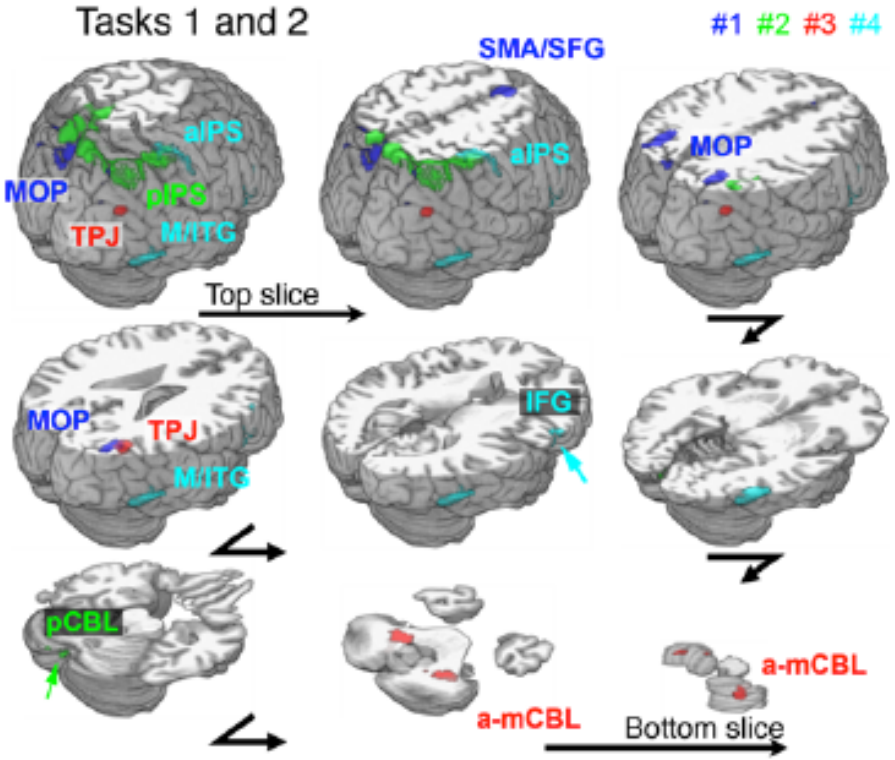


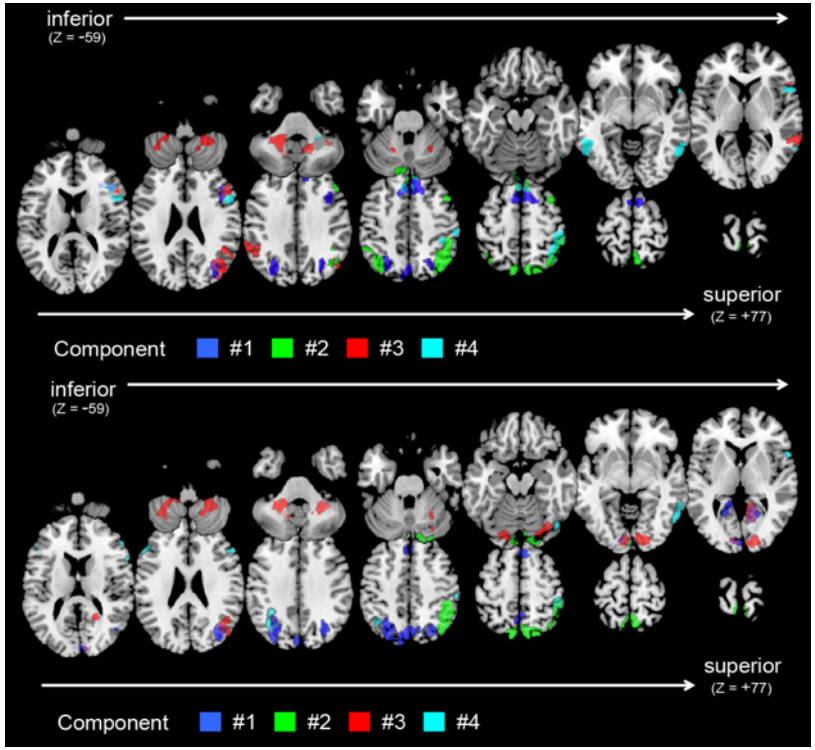


S Kim, K Ogawa, J Lv, N Scweighofer, H Imamizu, *PLoS Biology*, 2015

Four principal networks with different time scales

Applying the state-of-the-art sparse singular value decomposition method



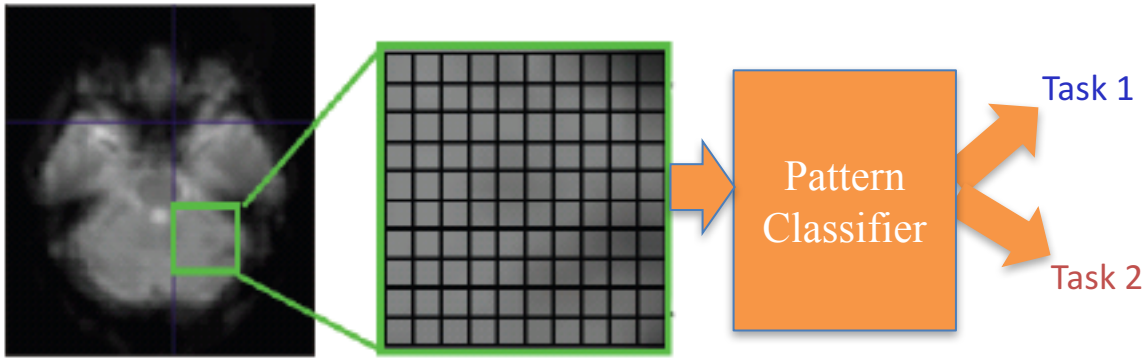


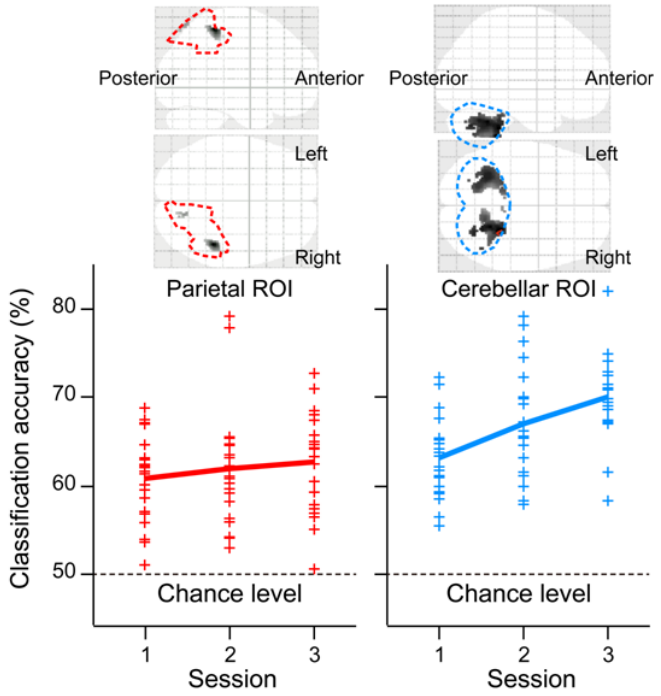
S Kim, K Ogawa, J Lv, N Scweighofer, H Imamizu, *PLoS Biology*, 2015

Multi-voxel pattern classification with machine learning techniques

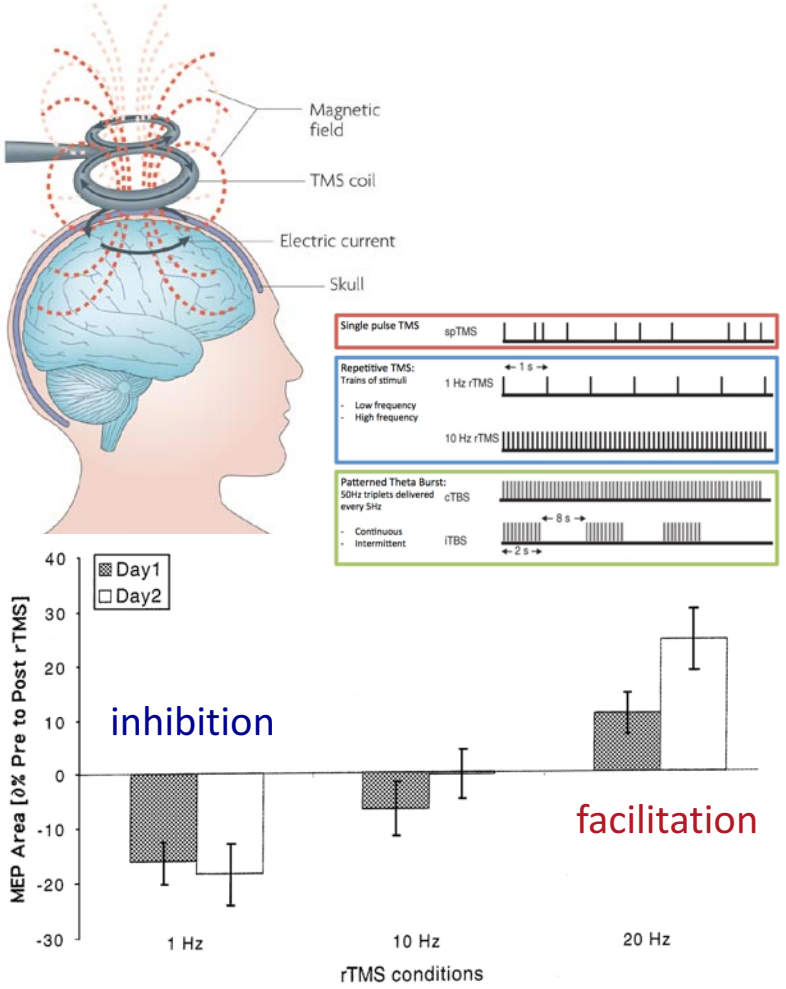
Classification of Task 1 vs. Task 2

- Linear Support Vector Machine, averaged classification accuracy reported



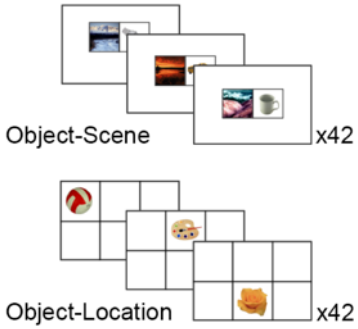


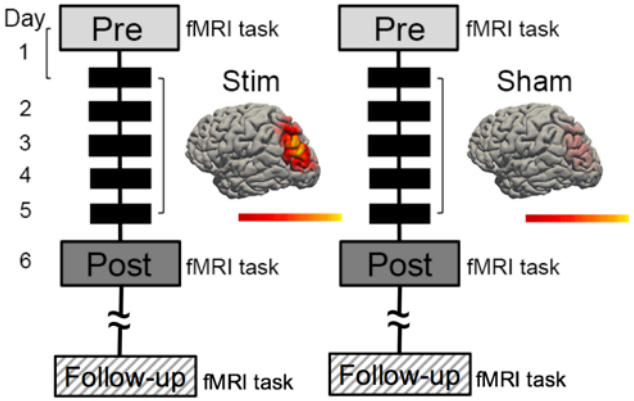
Non-invasive neuromodulation : Transcranial Magnetic Stimulation (TMS)

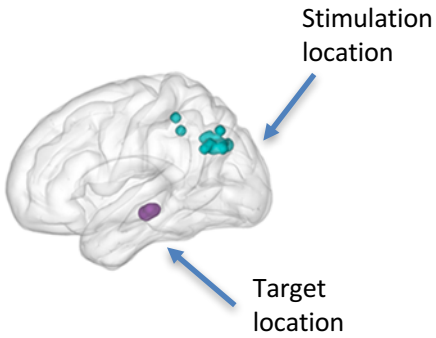


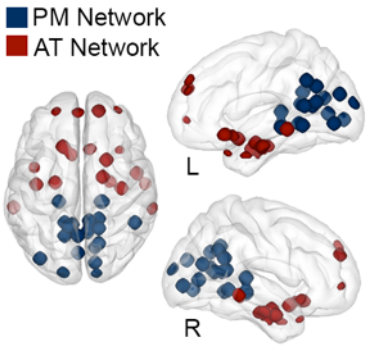
Maeda et al., *Clinical Neurophysiol,* 2000

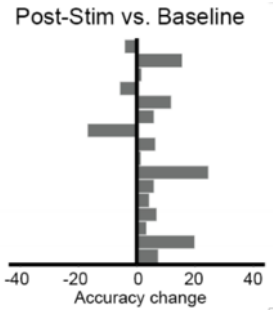
Targeted TMS selectively activate hippocampal-cortical memory network

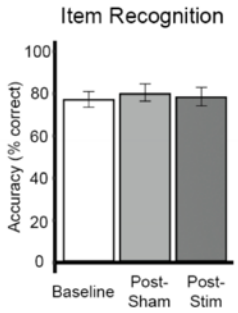


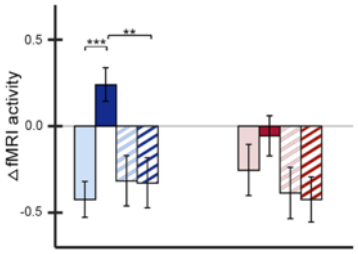


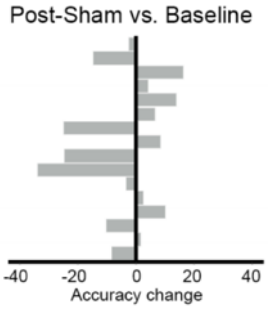


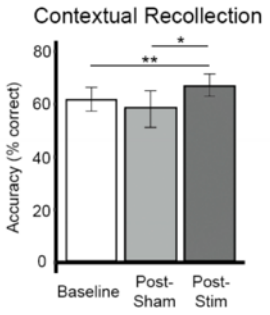








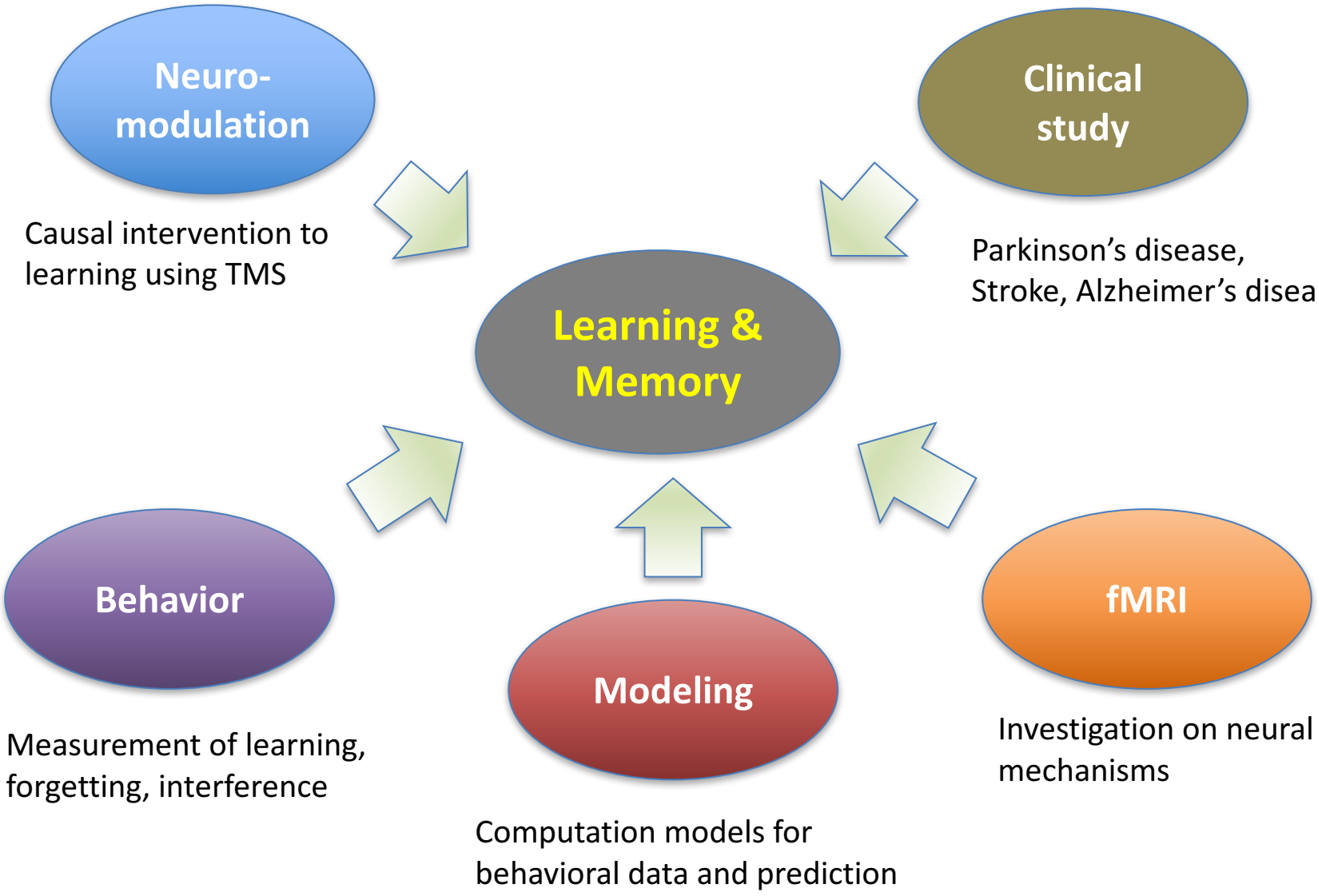




Kim et al., *Science Advances*, 2018

Current & Future Research

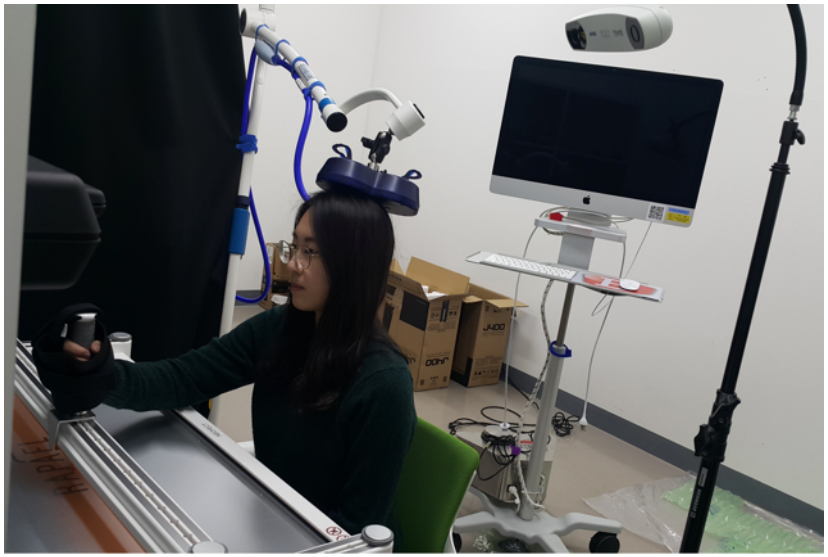
Multimodal approach to learning & memory



Setup of the laboratory

Visuomotor experiment setup

TMS with Neuronavigation system



Reaching task in fMRI scanner

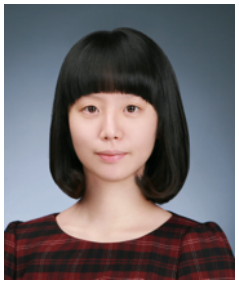
MR-compatible data glove

Our team members

Sungshin Kim
Principal Investigator

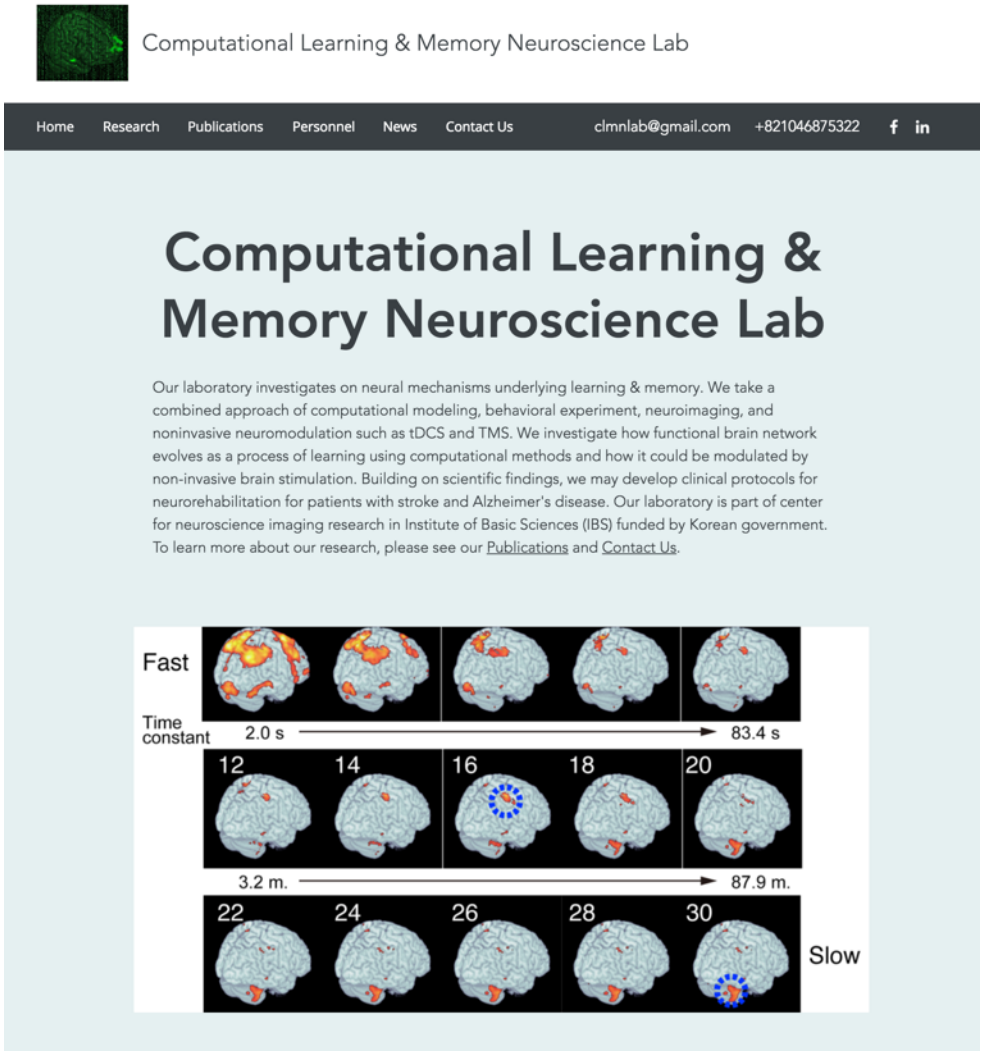
Kyusung Lim
Postdoc

Yunha Shin
To-be-hired



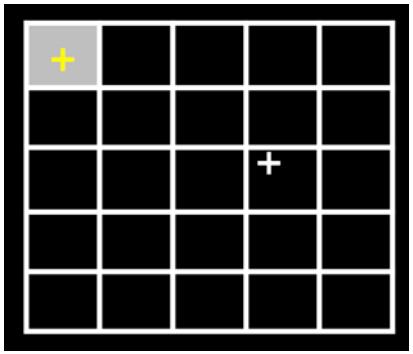
Yera Choi
To-be-hired

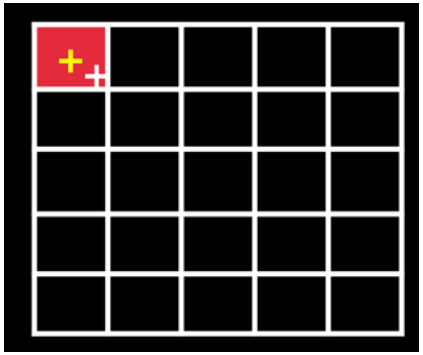
Nayeon Kwon
Student Intern

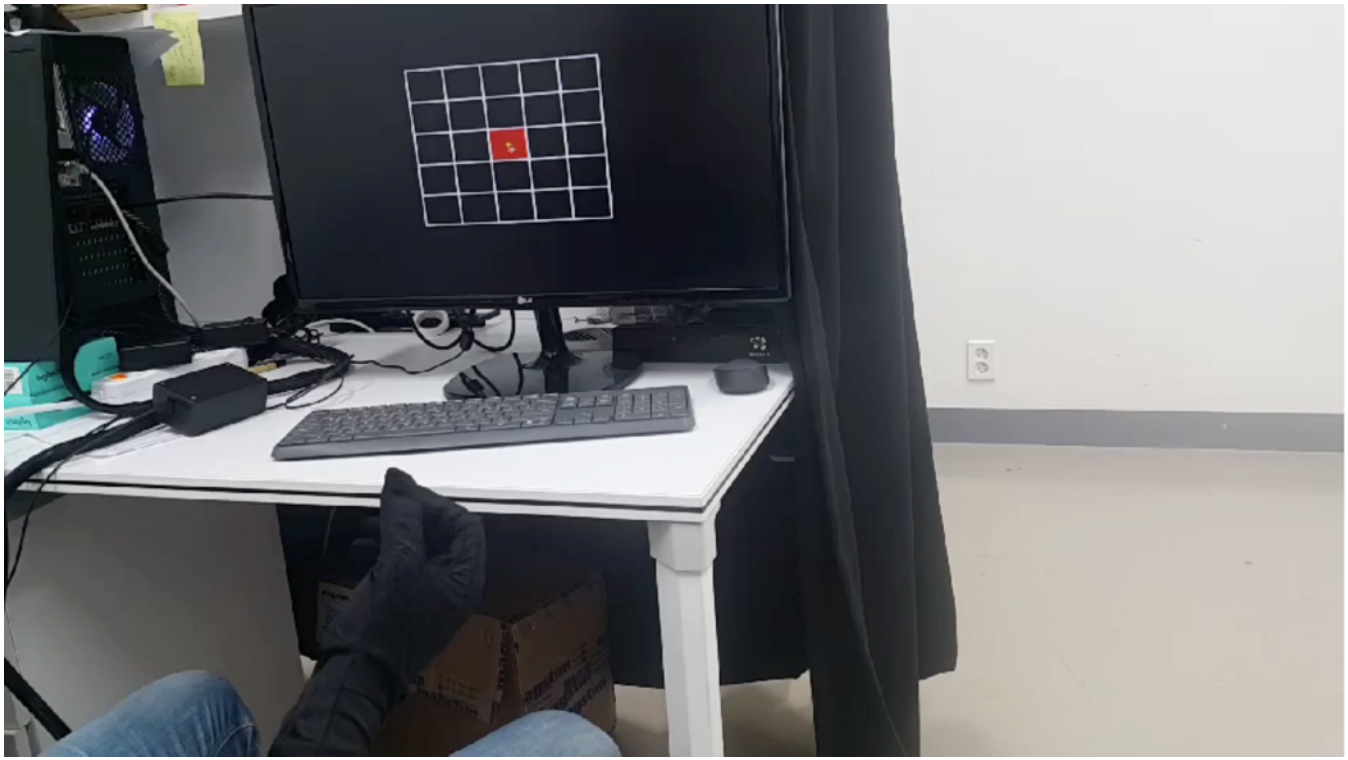


Topic 1: Neural correlates of reward-based motor skill learning in high-dimensional space

The first fMRI experiment of learning a new motor skill from scratch

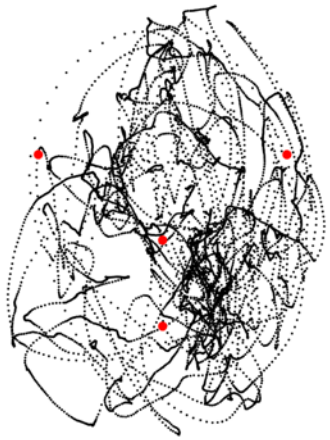




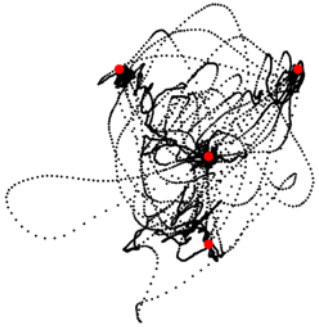


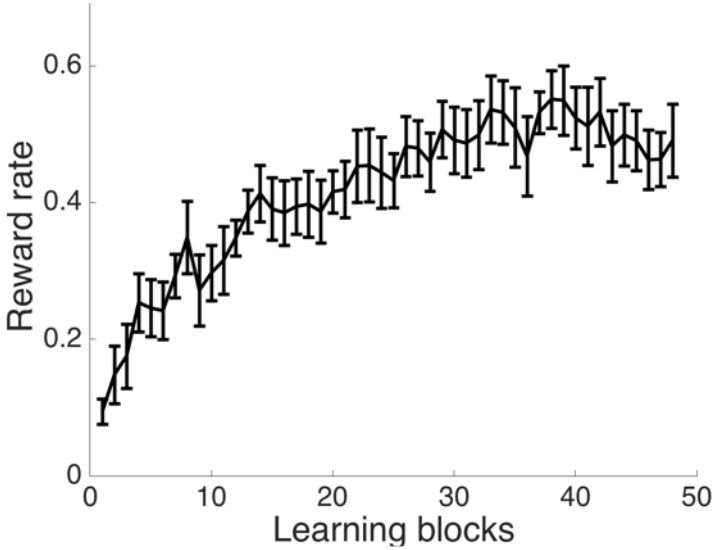
Preliminary behavioral and fMRI results

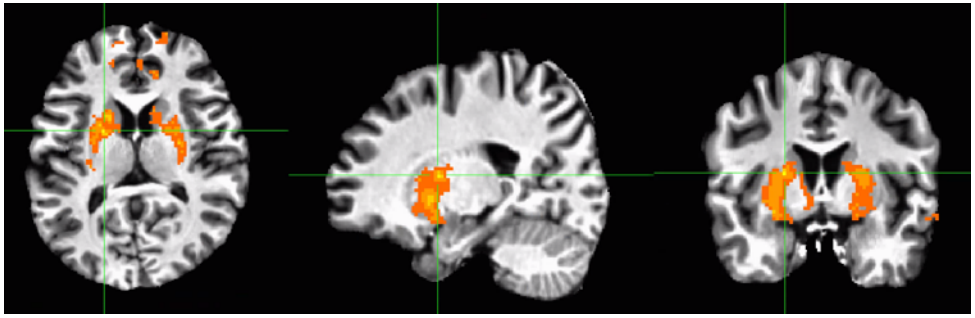
Early



Late



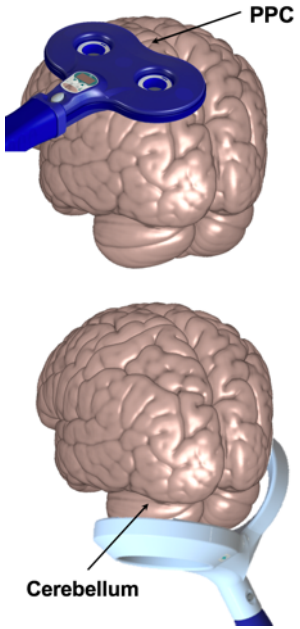


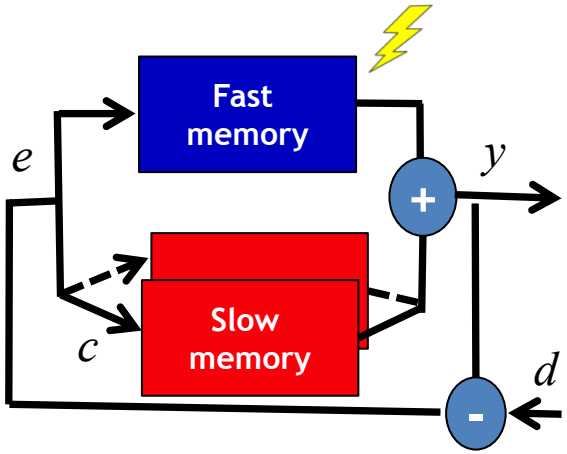


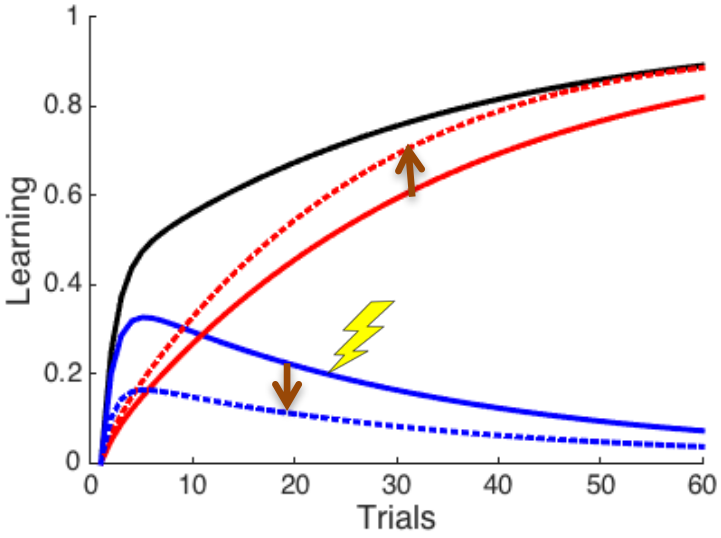
First fMRI demonstration in high-dimensional Learning motor skill from scratch

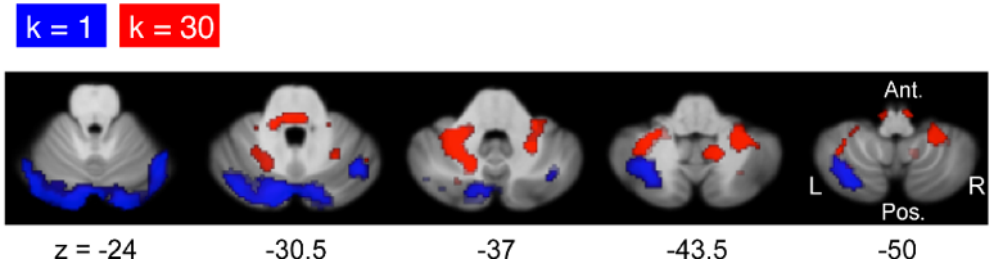
We found strong fMRI activities in bilateral putamen modulating reward during motor skill learning

Topic 2: TMS modulation of motor learning & memory

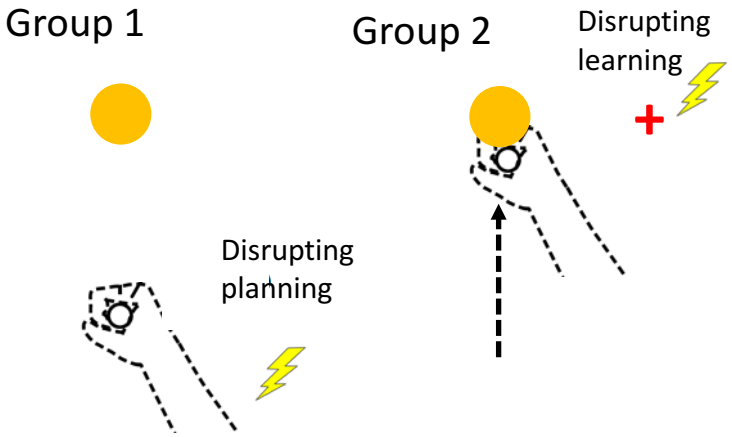








S Kim, et al., *PLoS Biology*, 2015



Thank you

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