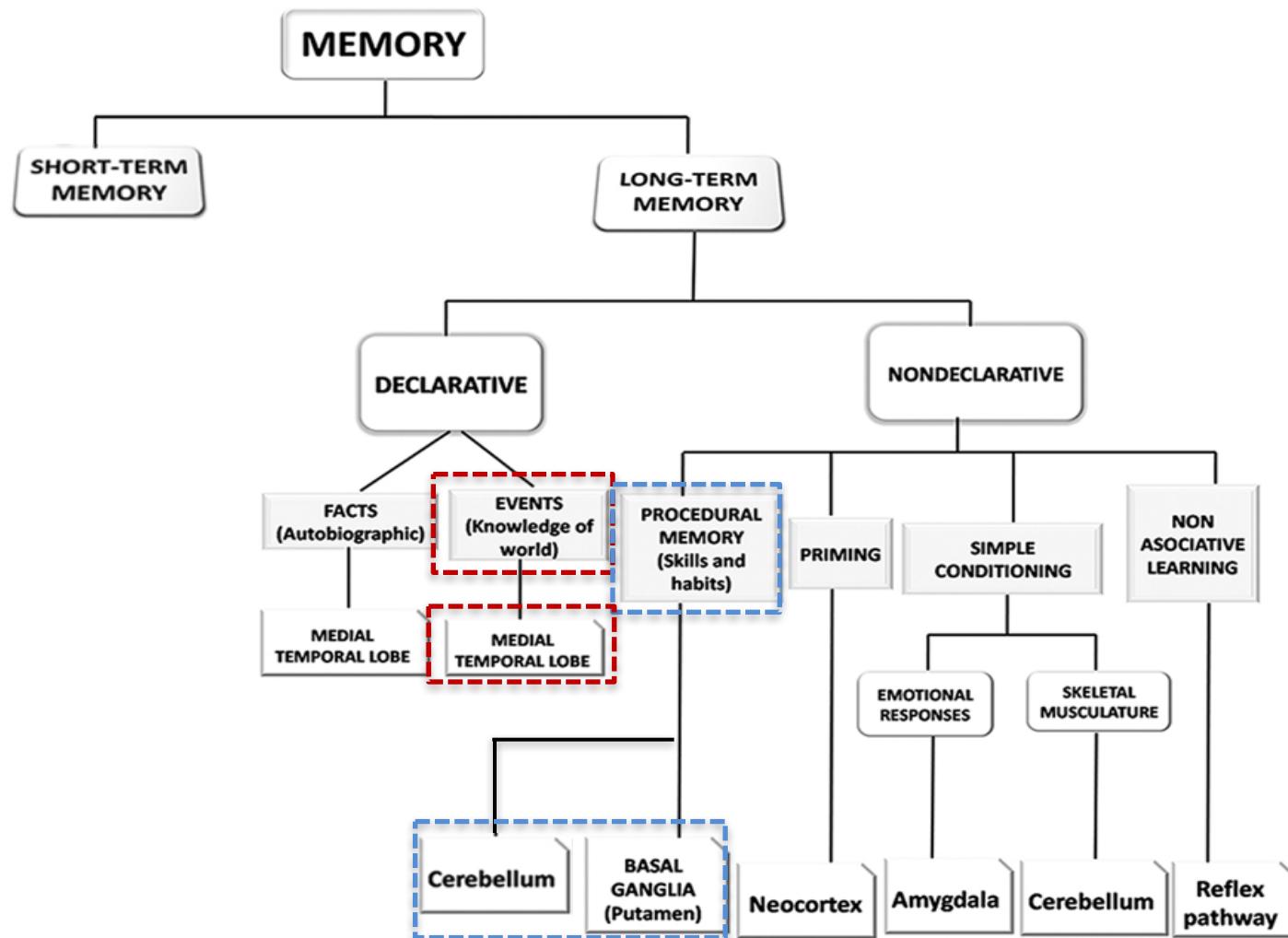


Research on Learning & Memory with Neuromodulation in CLMN lab

Presented by
Sungshin Kim
June, 30, 2018

<http://clmnlab.com>

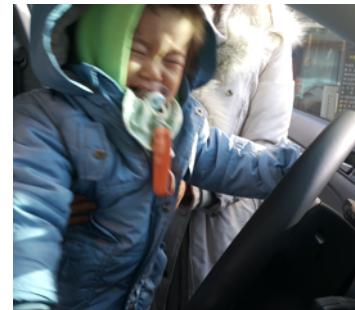
Taxonomy of biological memory



Why motor Learning?

Our life is a continuum of motor learning

Learning new motor skills



Adapting to changes

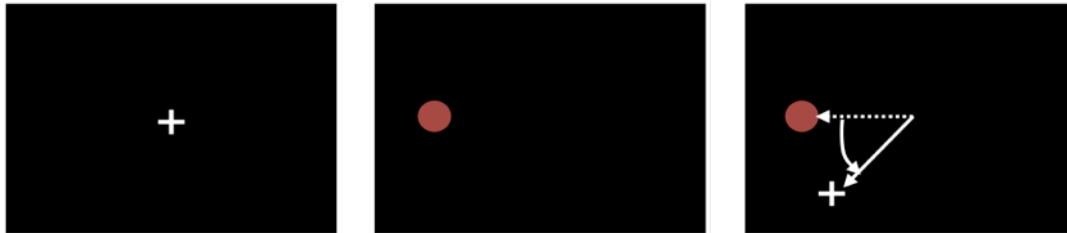


Regaining lost motor skills

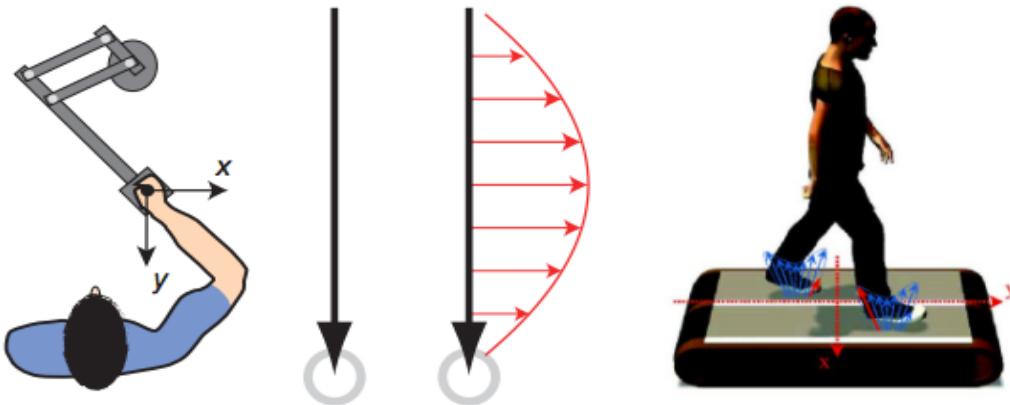
Two types of motor learning

1. Motor adaptation

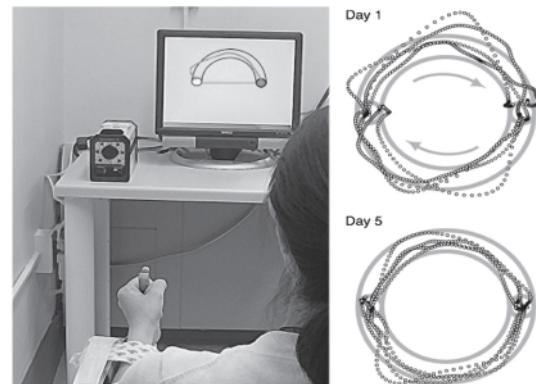
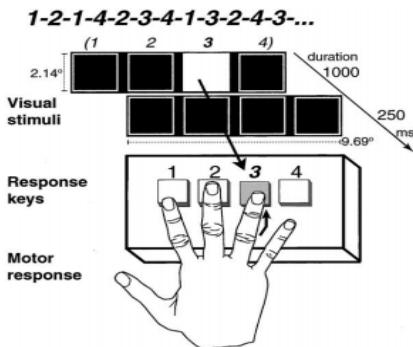
(1) visuomotor adaptation (kinematics)



(2) force-field adaptation (dynamics)



2. Motor skill learning



Advantage of motor learning research:

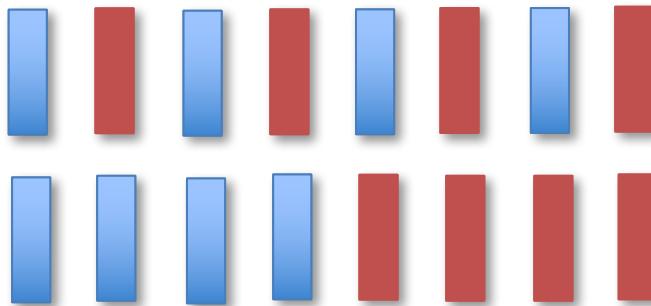
- ✓ Easy to quantify the amount of learning
- ✓ Possible to measure progress of learning
- ✓ Theoretical & computational approaches with models are encouraged

But, within-subject experiment design is difficult

Effects of task schedule on motor learning

Interference between tasks

- Contextual interference effect



Grade: A

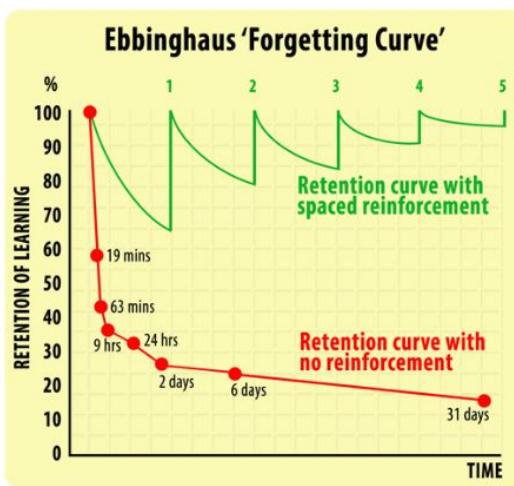


Grade: B



Time decay of memory

- Spacing effect



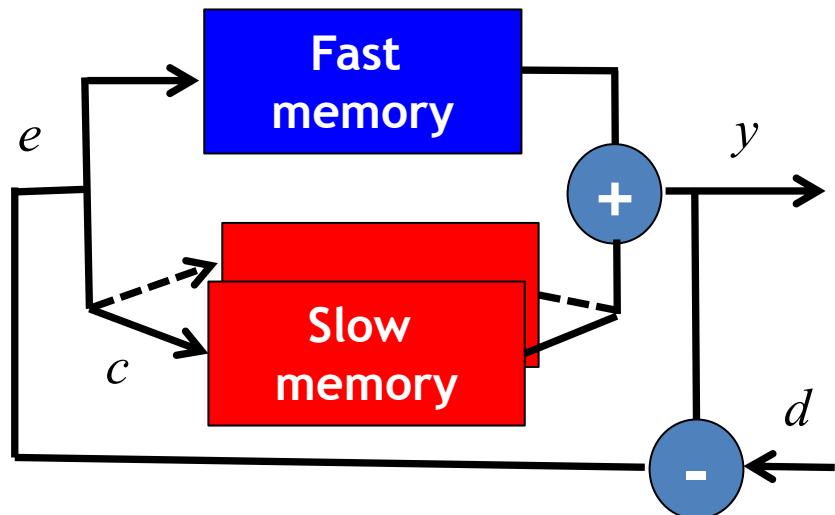
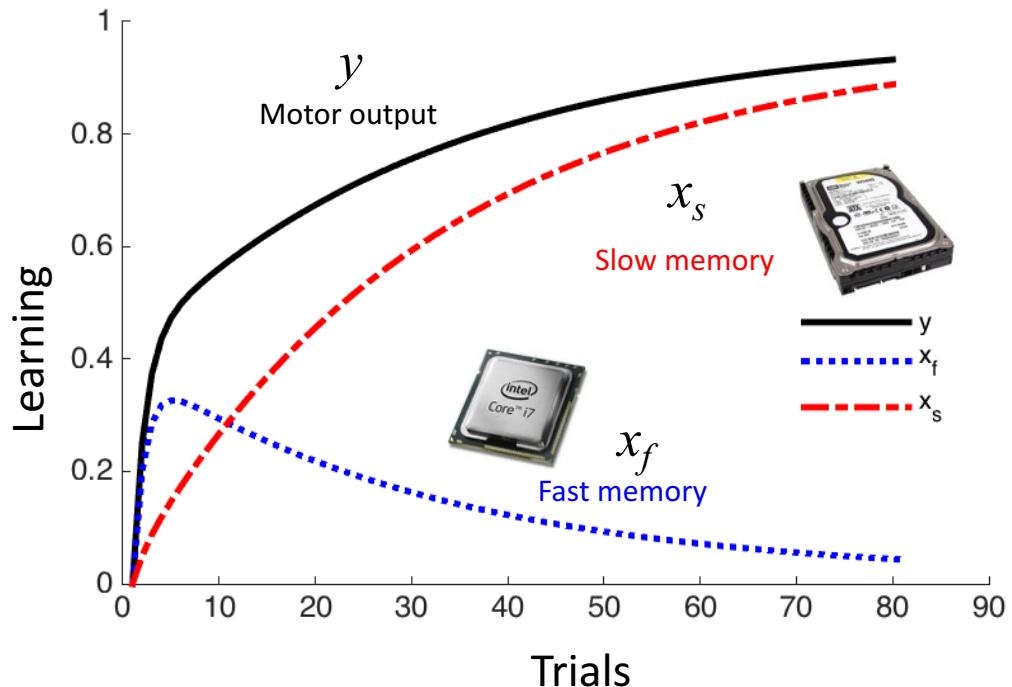
Grade: A

Grade: B



Grade: C

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

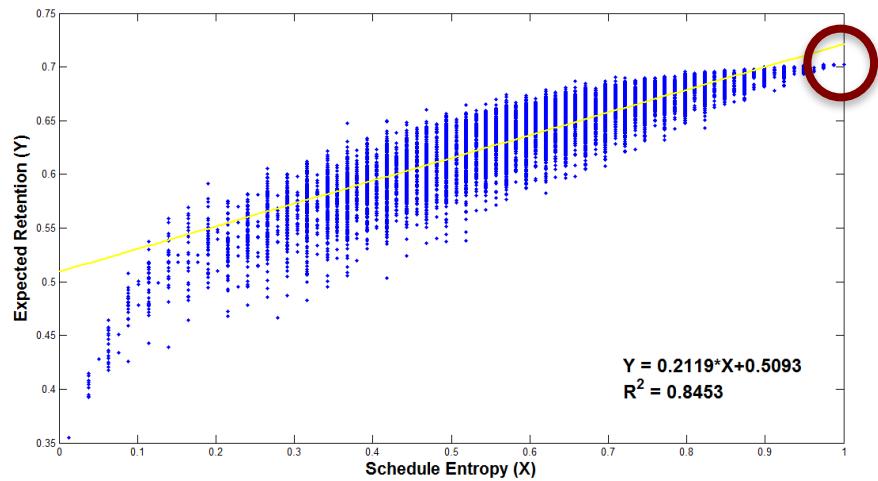
In search of optimal learning schedule

2018 JUNE						
SUN	MON	TUE	WED	THU	FRI	SAT
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30

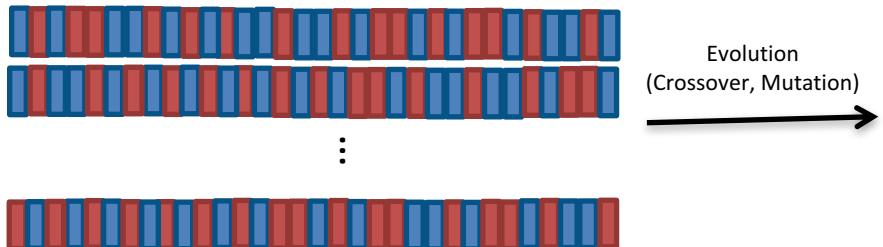
www.free-printable-calendar.com



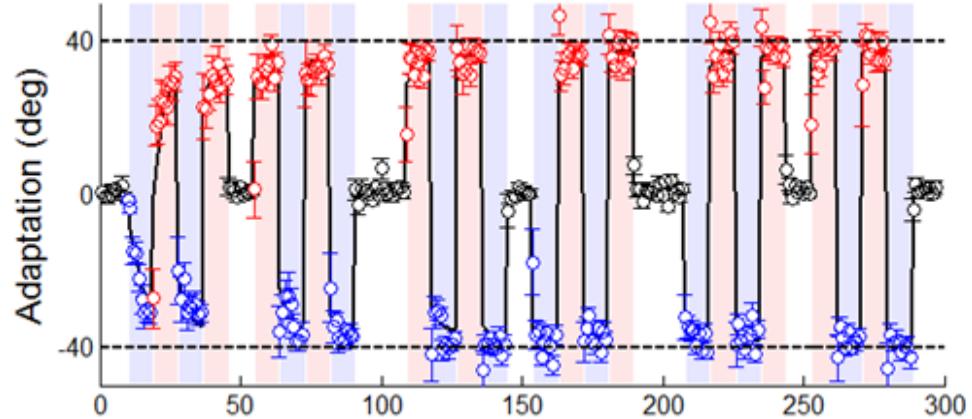
Best schedules for both two tasks?
 $2^{31} \approx 2 \times 10^9$ possible schedules!



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



Neural substrates of memories with multiple time scales (modeling)

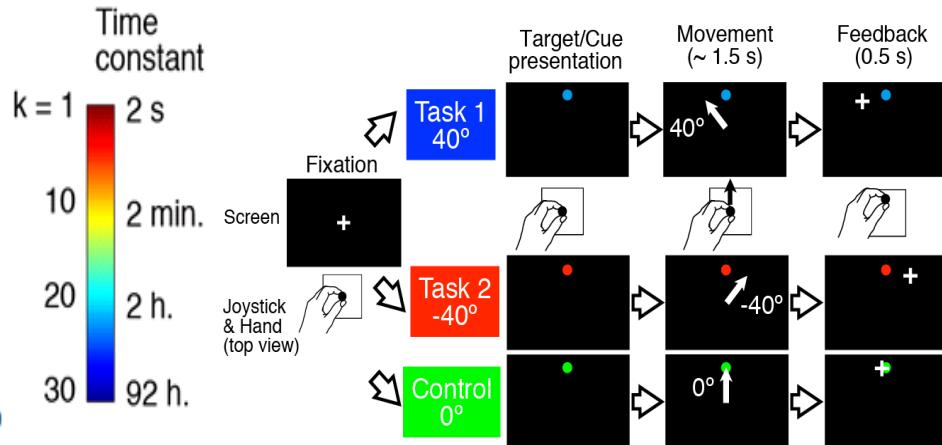
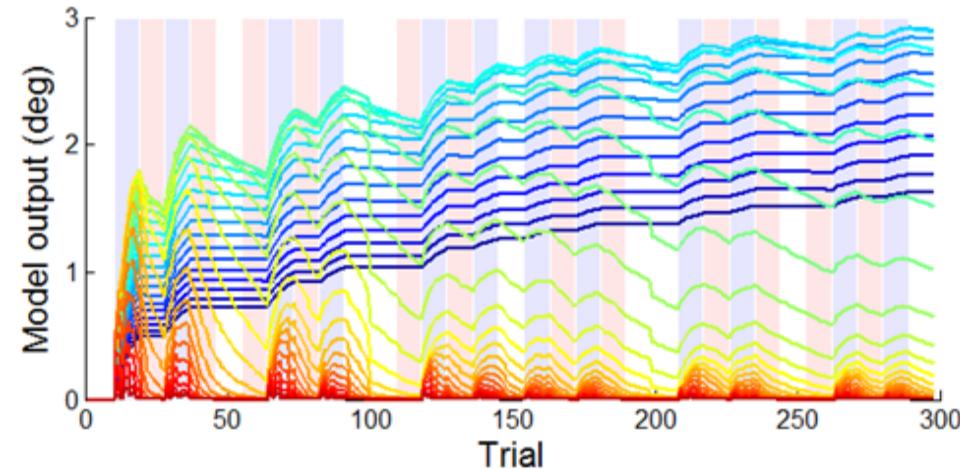


$$y(n) = \sum_{k=1}^{30} \mathbf{x}_k(n)^T \mathbf{c}(n)$$

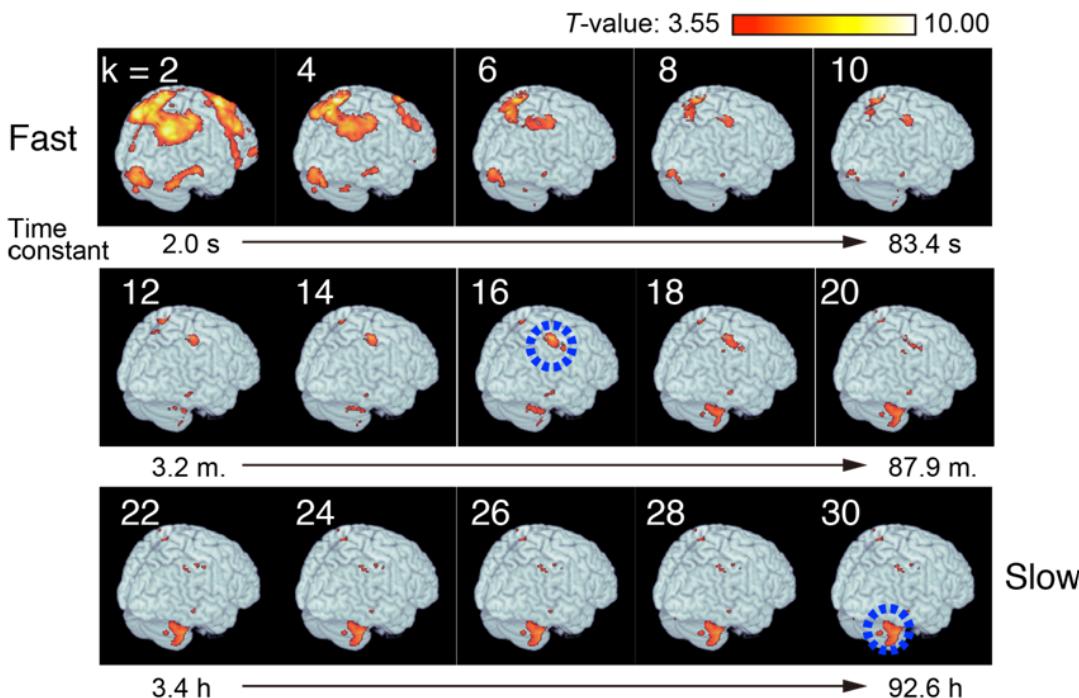
$$\mathbf{x}_k(n+1) = \mathbf{x}_k(n) \boxed{\exp(-T(n)/\tau_k)} + \boxed{\beta_k \cdot e(n) \cdot \mathbf{c}(n)}$$

Forgetting Learning

$$\text{RMSE} = 4.96^\circ, R^2 = 0.981 \quad \beta_k = \frac{r}{\tau_k^q} \quad (k = 1, \dots, 30)$$

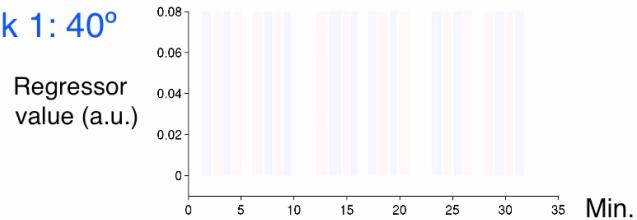


Neural substrates of memories with multiple time scales (fMRI results)

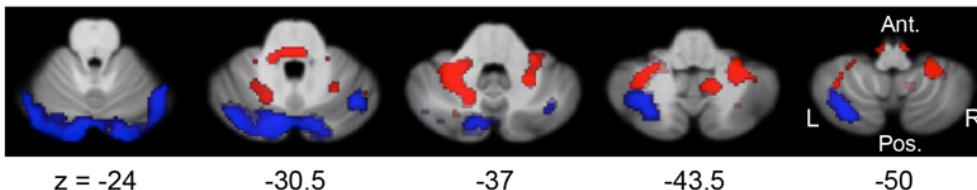
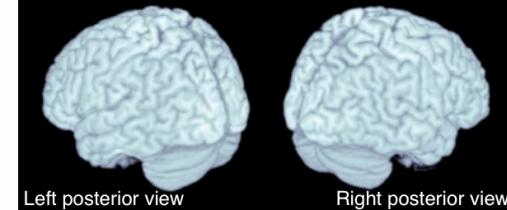


Regression results

- Task 1: 40°

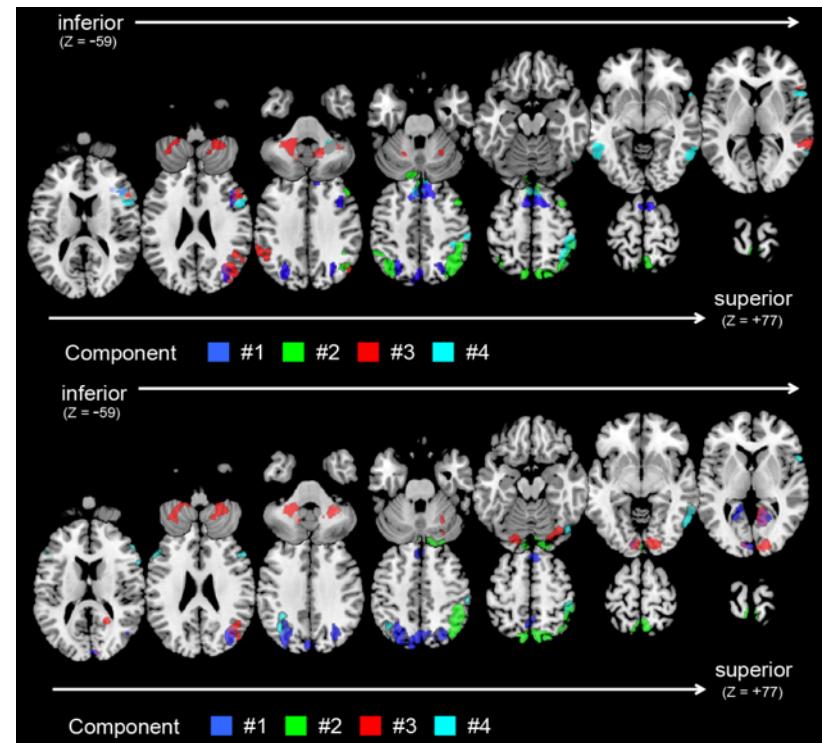
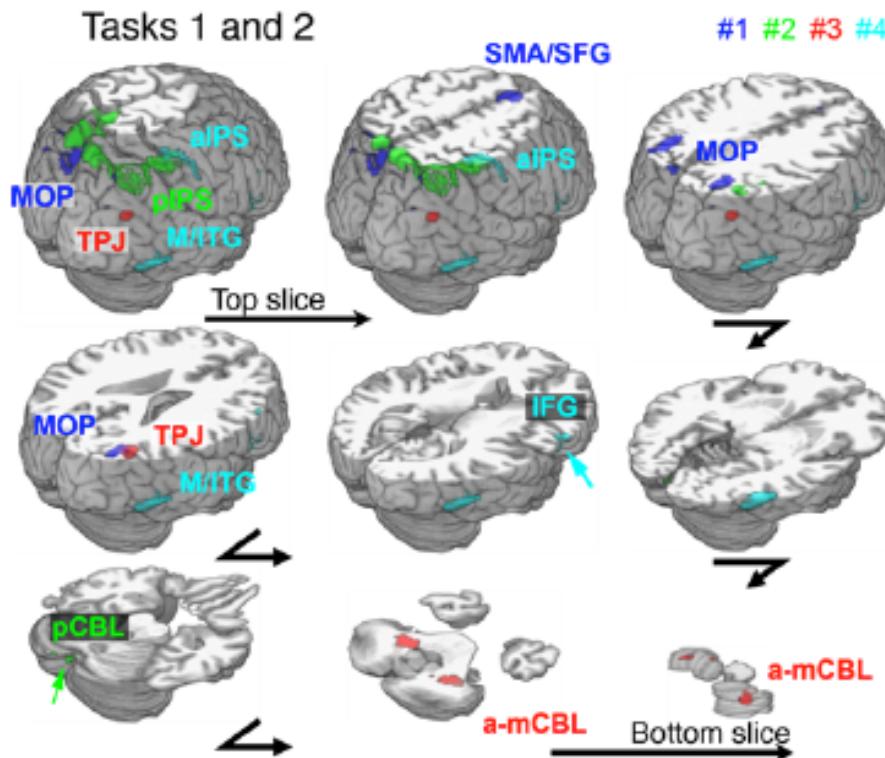


Activity correlated with each regressor



Four principal networks with different time scales

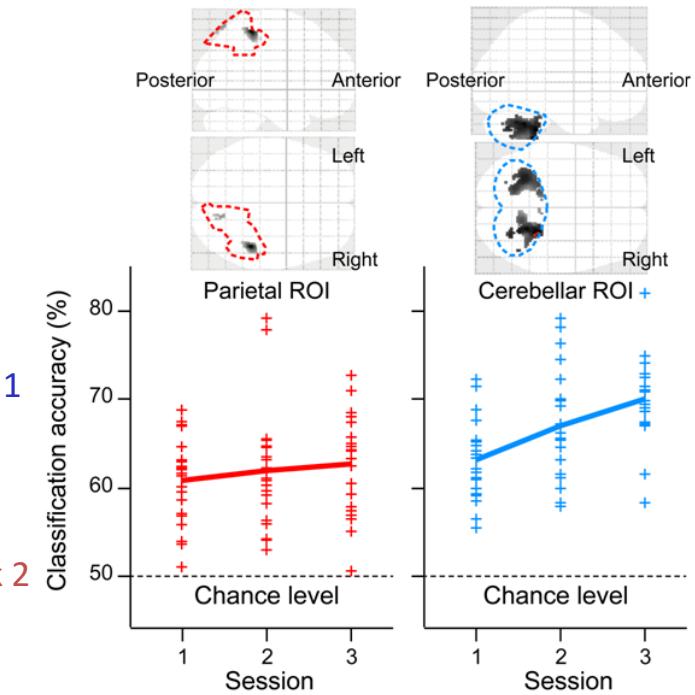
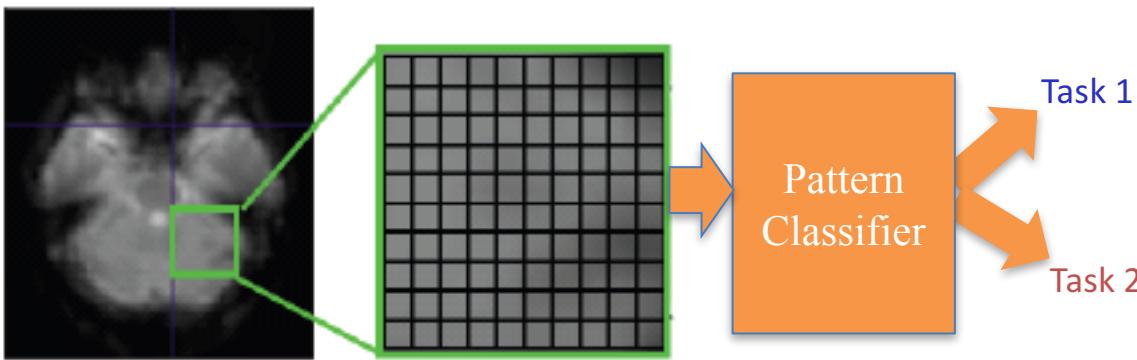
Applying the state-of-the-art sparse singular value decomposition method



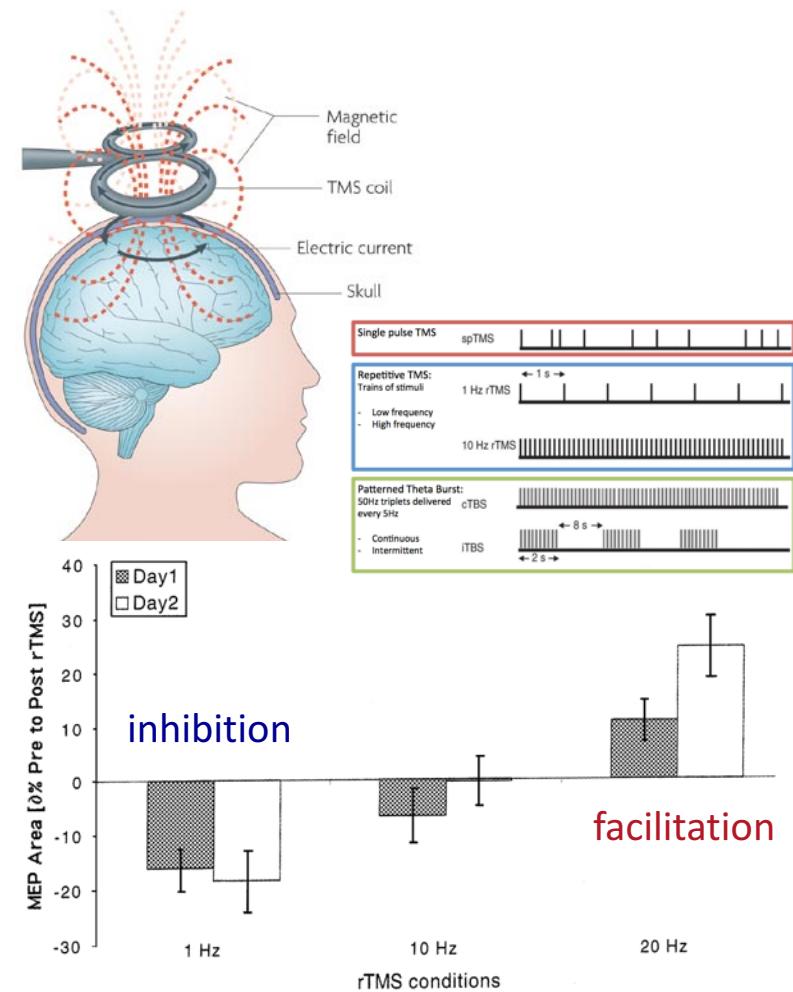
Multi-voxel pattern classification with machine learning techniques

Classification of Task 1 vs. Task 2

- Linear Support Vector Machine, averaged classification accuracy reported

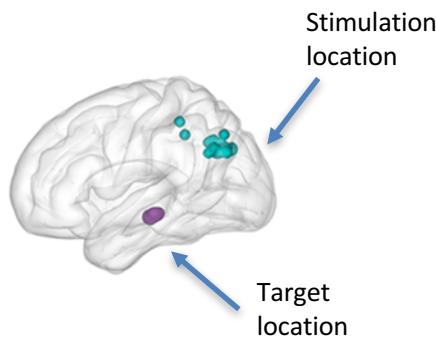
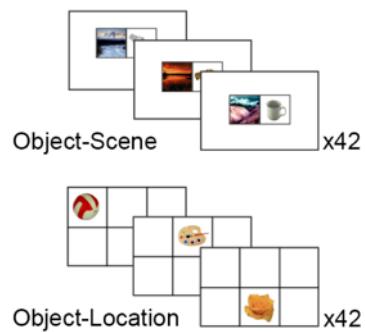


Non-invasive neuromodulation : Transcranial Magnetic Stimulation (TMS)

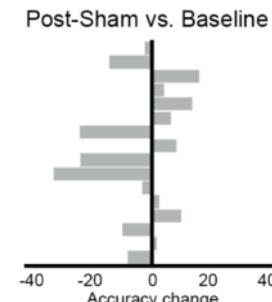
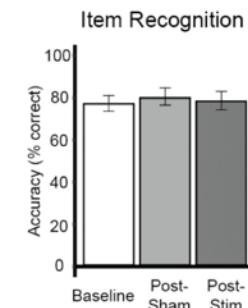
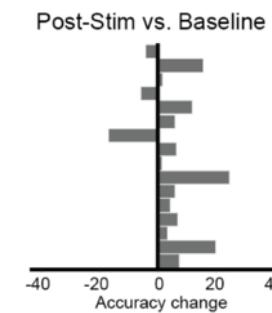
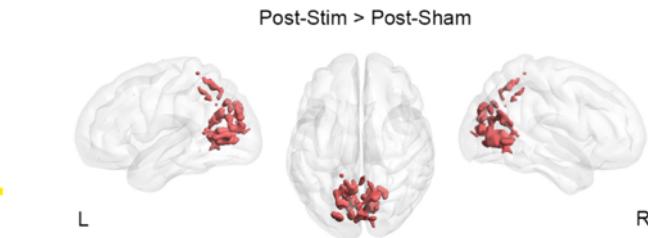
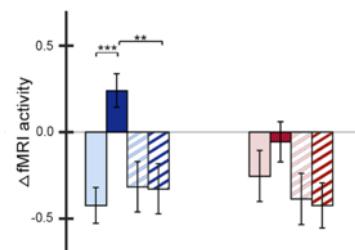
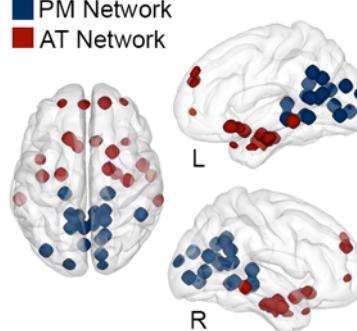
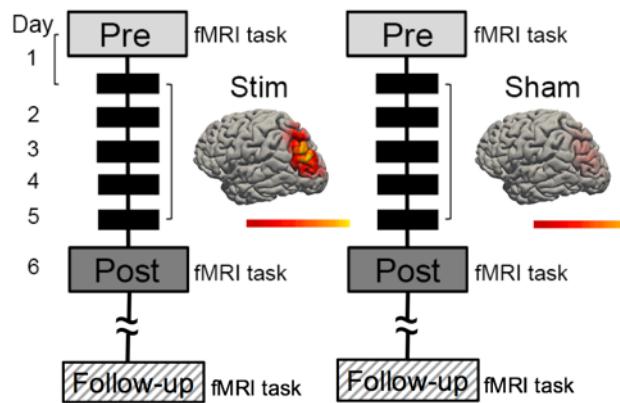


Maeda et al., *Clinical Neurophysiol*, 2000

Targeted TMS selectively activate hippocampal-cortical memory network

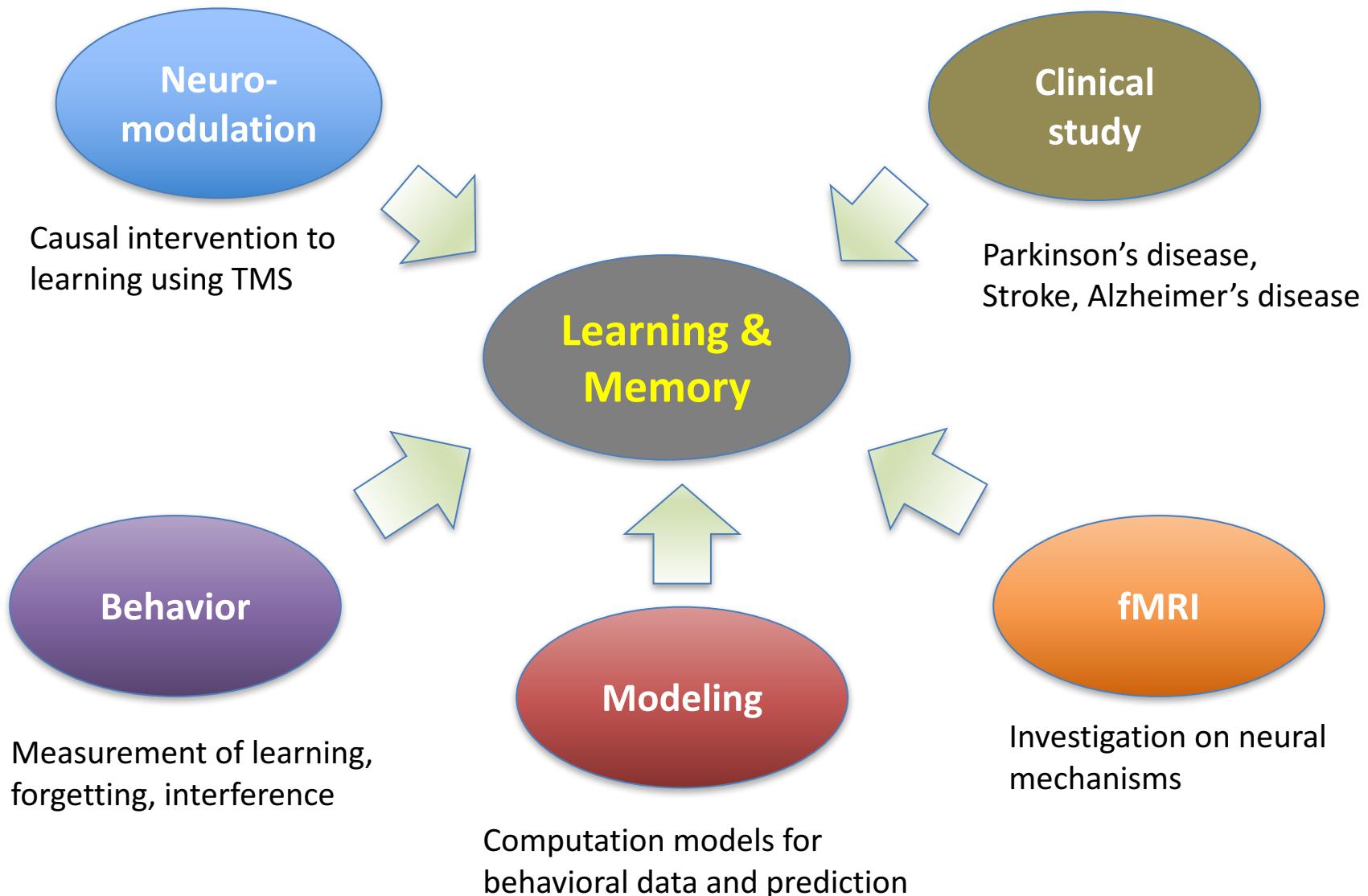


PM Post Sham Post Stim Sham Follow-up Stim Follow-up
AT Post Sham Post Stim Sham Follow-up Stim Follow-up



Current & Future Research

Multimodal approach to learning & memory

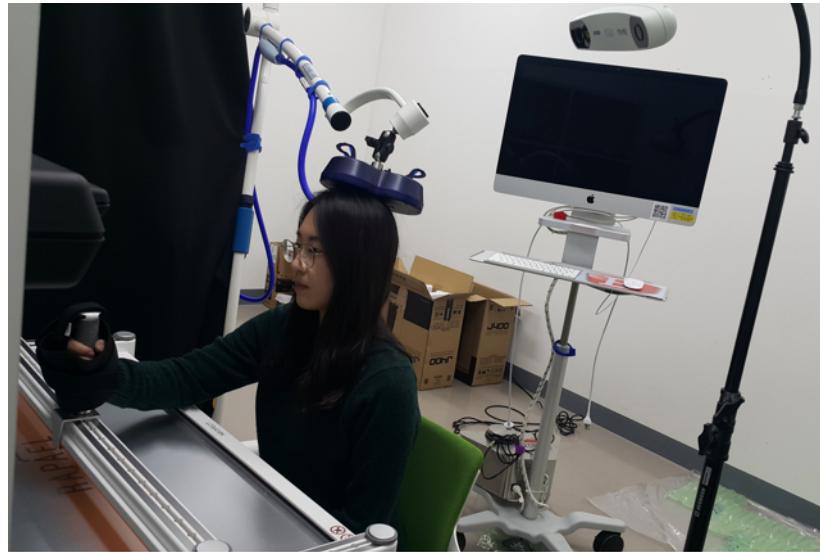


Setup of the laboratory

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

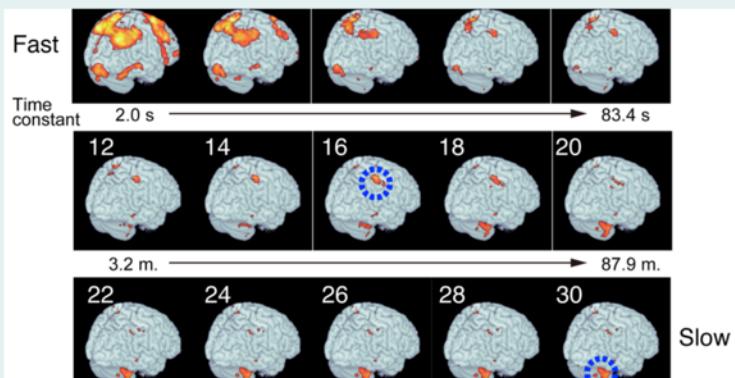


Computational Learning & Memory Neuroscience Lab

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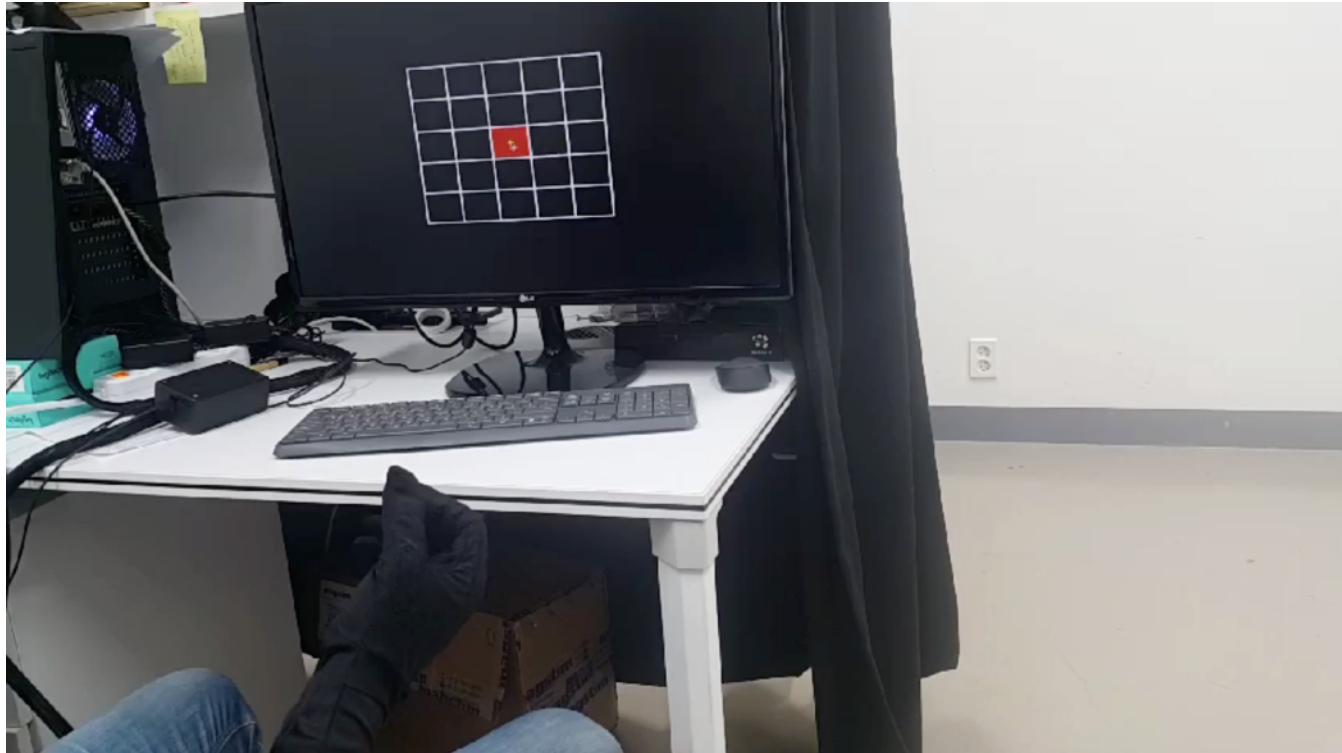
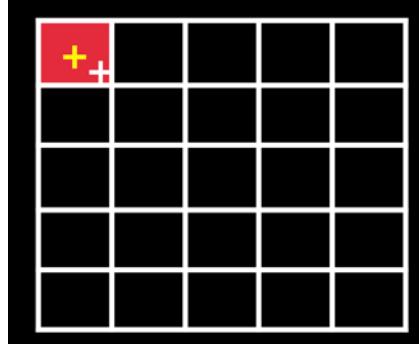
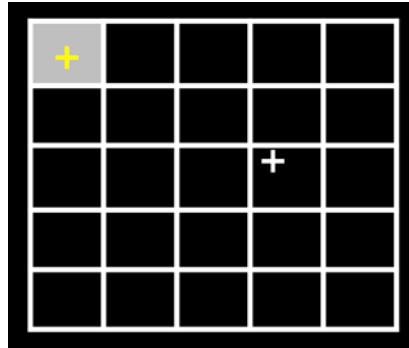
Computational Learning & Memory Neuroscience Lab

Our laboratory investigates on neural mechanisms underlying learning & memory. We take a combined approach of computational modeling, behavioral experiment, neuroimaging, and noninvasive neuromodulation such as tDCS and TMS. We investigate how functional brain network evolves as a process of learning using computational methods and how it could be modulated by non-invasive brain stimulation. Building on scientific findings, we may develop clinical protocols for neurorehabilitation for patients with stroke and Alzheimer's disease. Our laboratory is part of center for neuroscience imaging research in Institute of Basic Sciences (IBS) funded by Korean government. To learn more about our research, please see our [Publications](#) and [Contact Us](#).



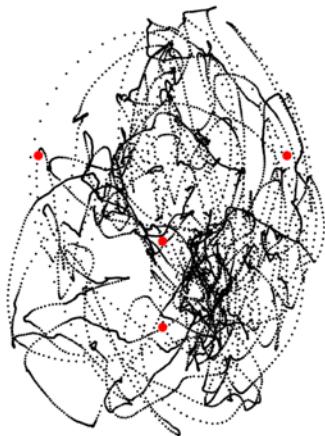
Topic 1: Neural correlates of reward-based motor skill learning in high-dimensional space

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

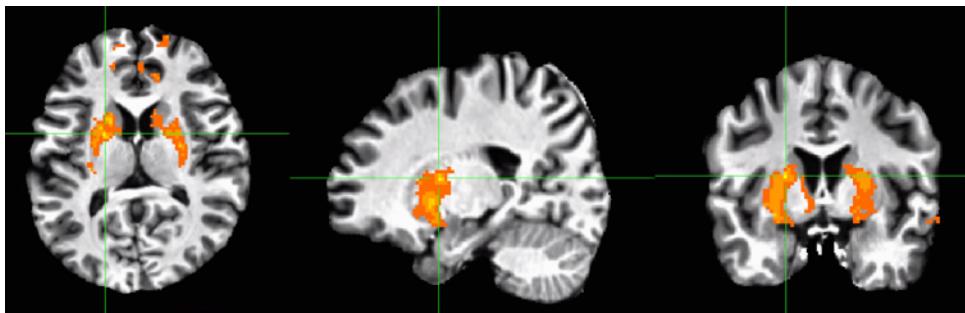
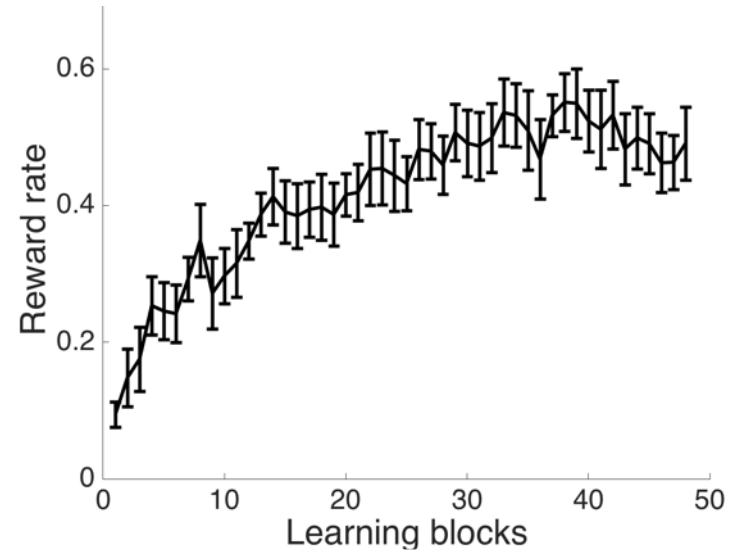
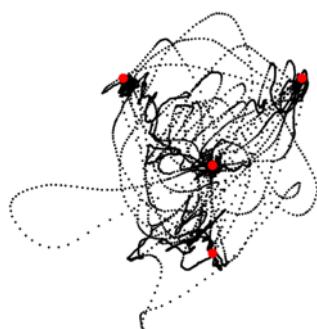


Preliminary behavioral and fMRI results

Early

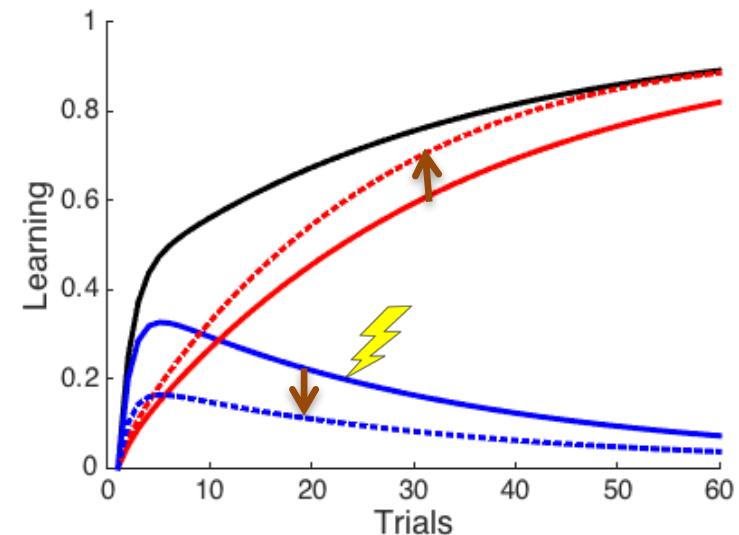
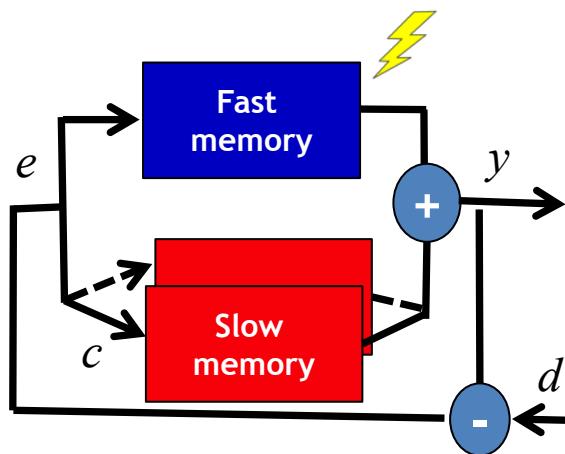
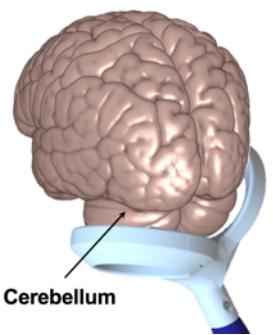
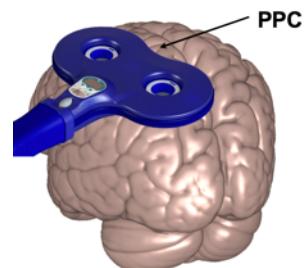


Late

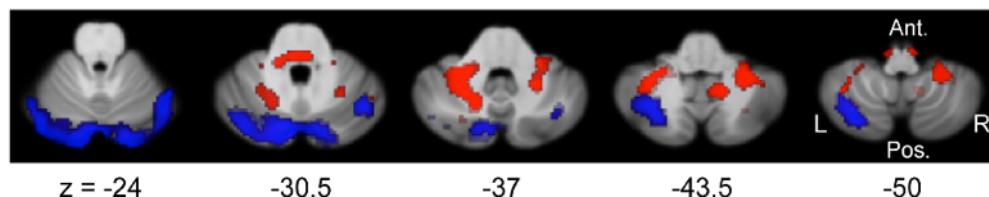


First fMRI demonstration in high-dimensional Learning motor skill from scratch
We found strong fMRI activities in bilateral putamen modulating reward during motor skill learning

Topic 2: TMS modulation of motor learning & memory



$k = 1$ $k = 30$

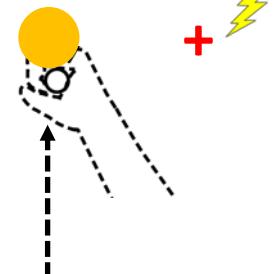


S Kim, et al., PLoS Biology, 2015

Group 1



Group 2



Disrupting
learning



Thank you

