Sungshin Kim

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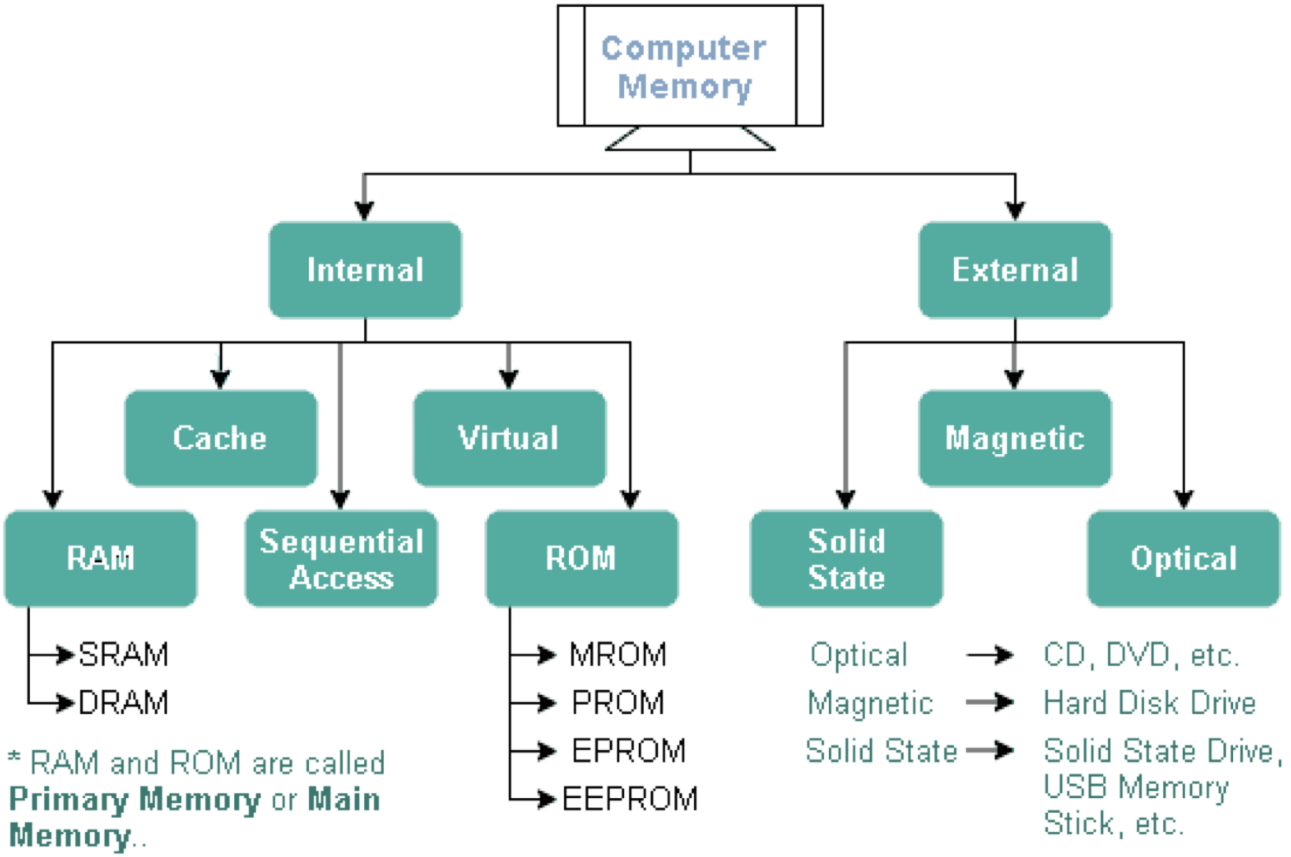
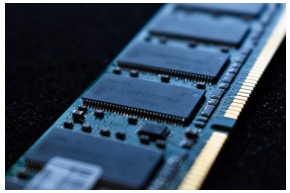
http://clmnlab.com

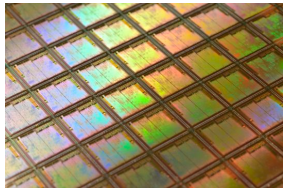
Recent studies on human learning and memory using neuroimaging and non-invasive brain stimulation

Date: Feb 25 (Thu), 2021
한국뇌공학회 심포지엄

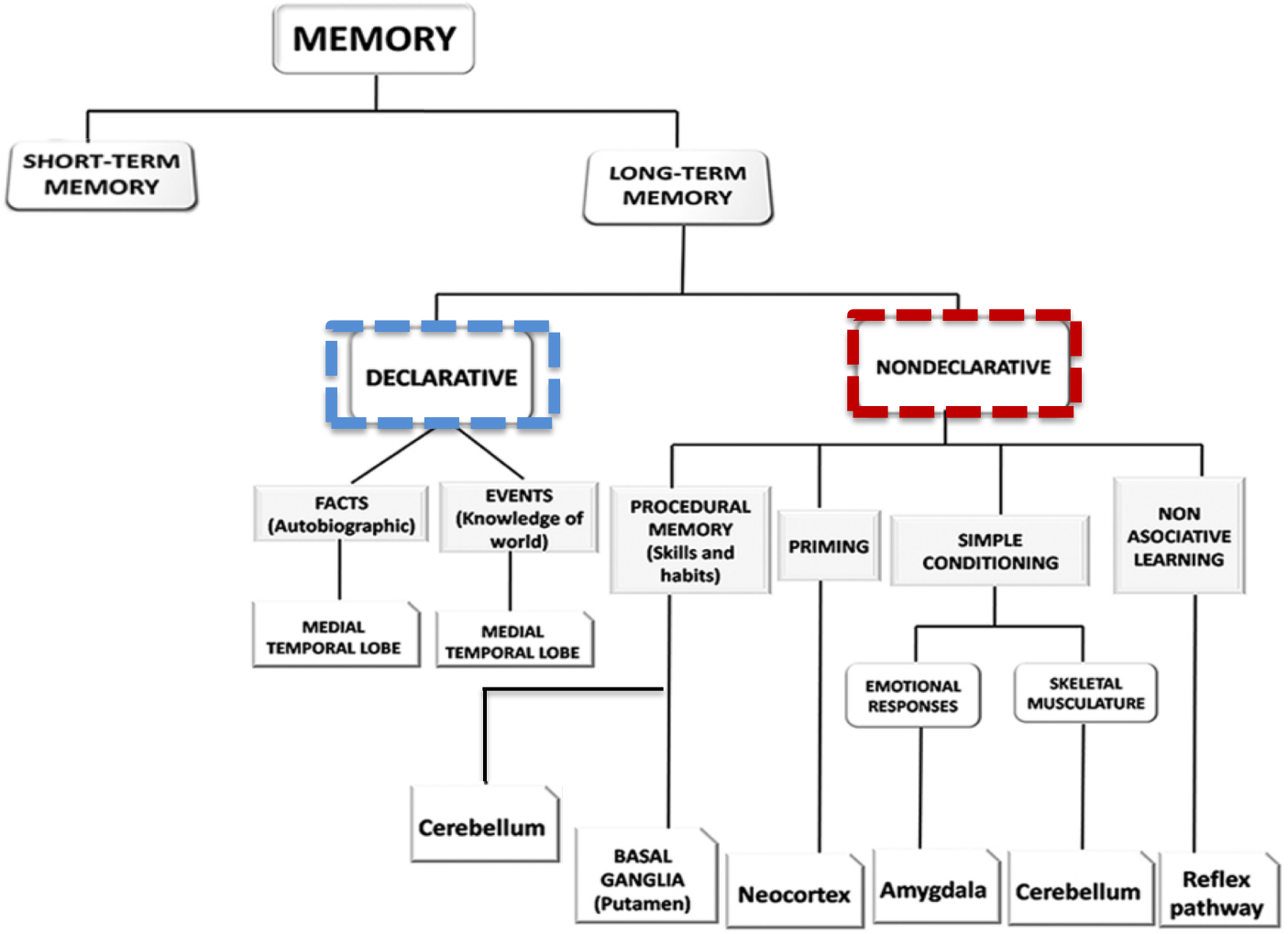
Types of computer memory



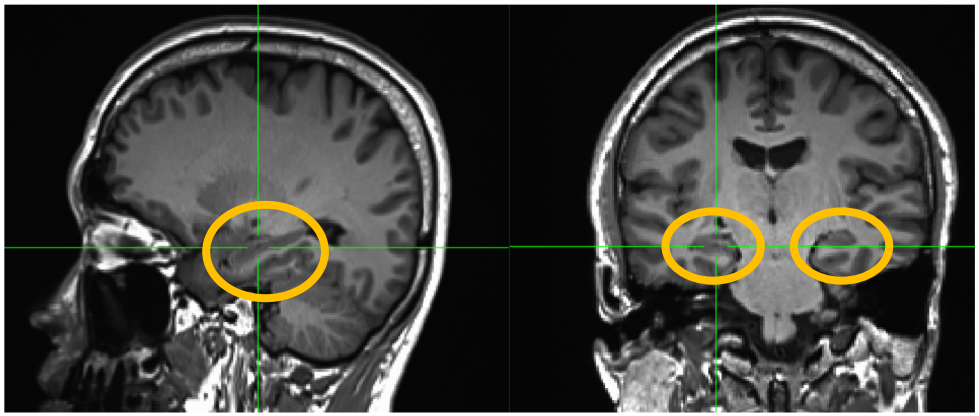


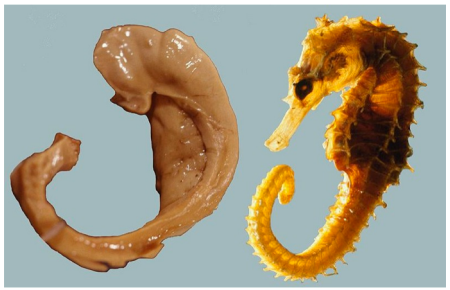


Types of biological memory

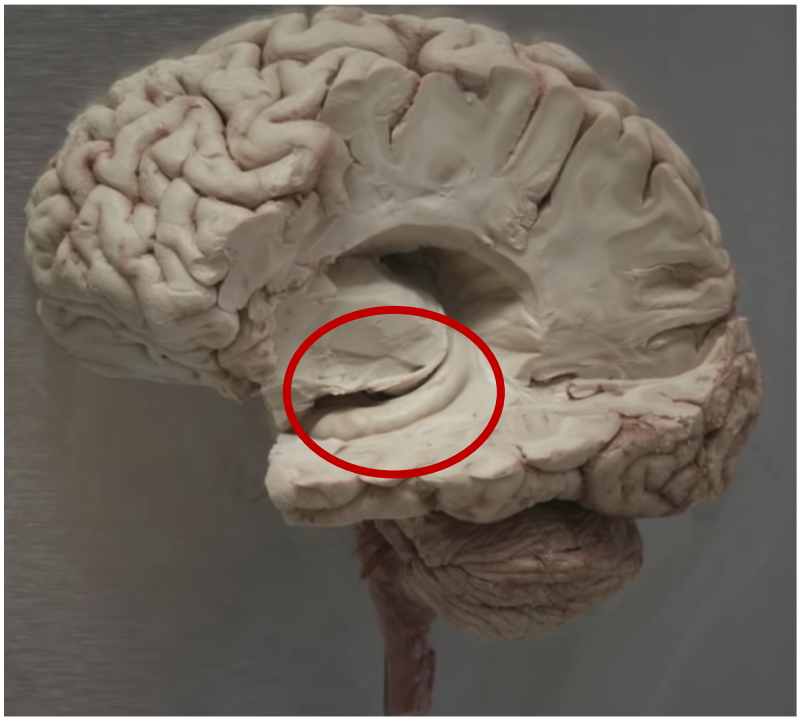


Declarative memory: Hippocampus



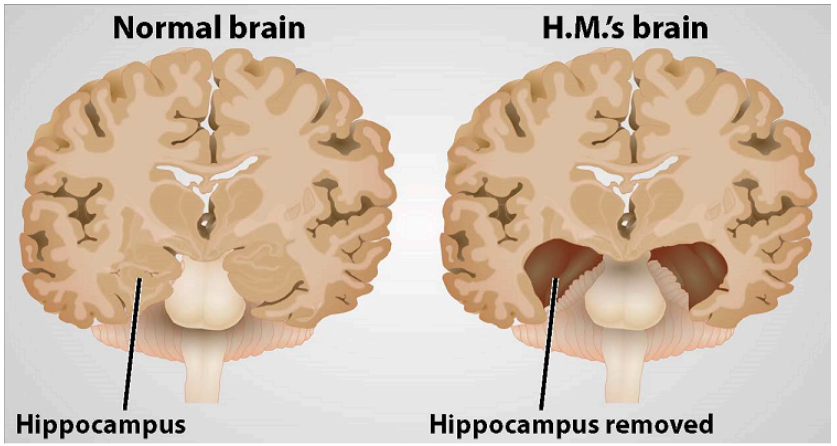


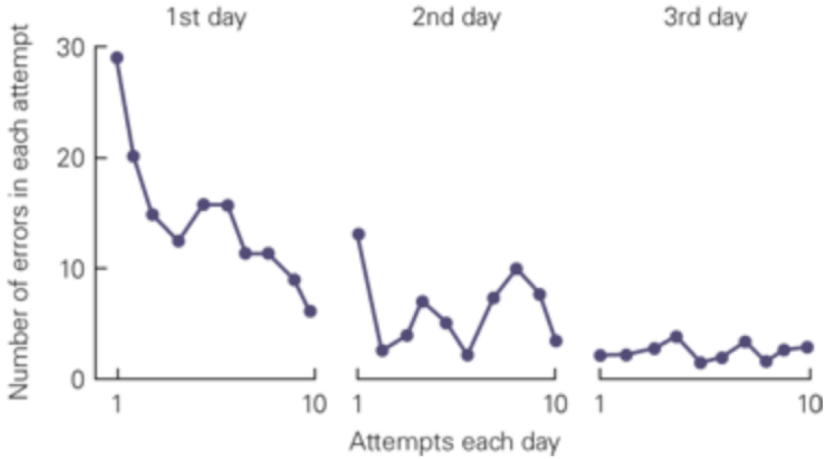
Left: Hippocampus + fornix
Right: Seahorse



Patient HM – Revolution of neuroscience

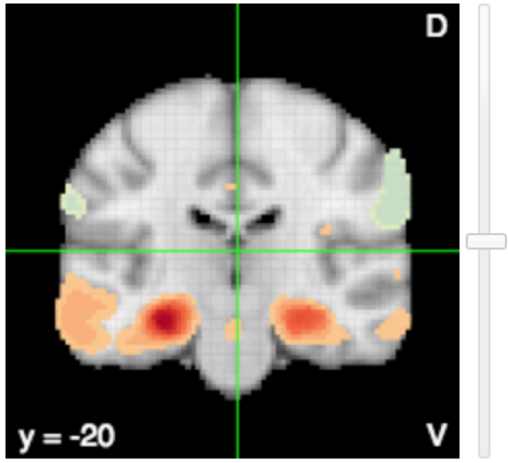
Henry Molarison (1926-2008)
Anterograde amnesia

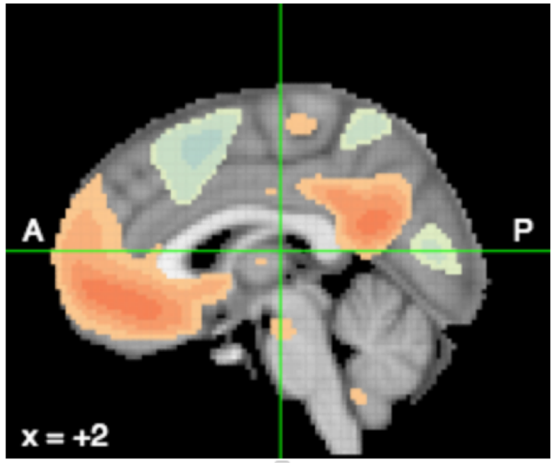


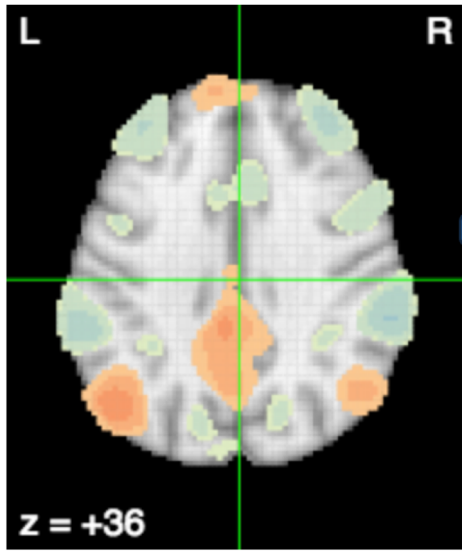


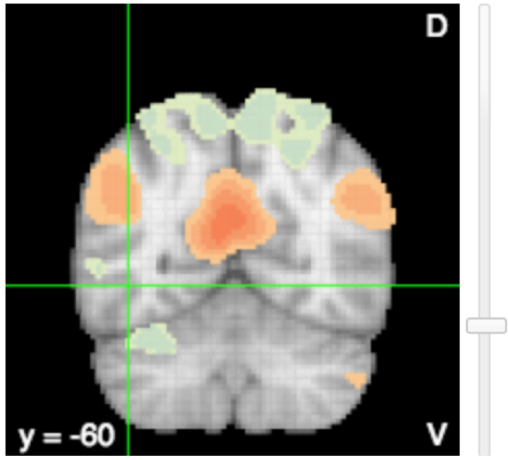
Impaired declarative memory
But, intact motor memory

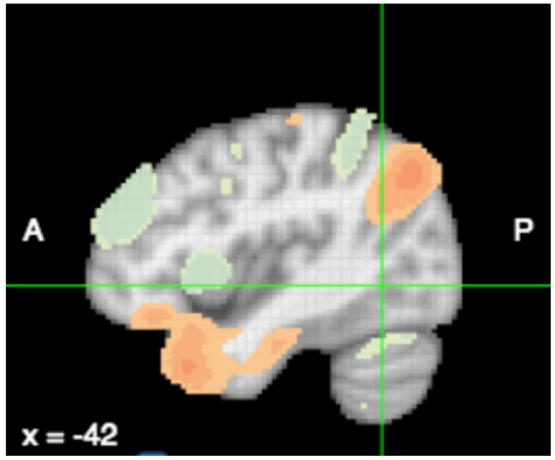
Default mode network











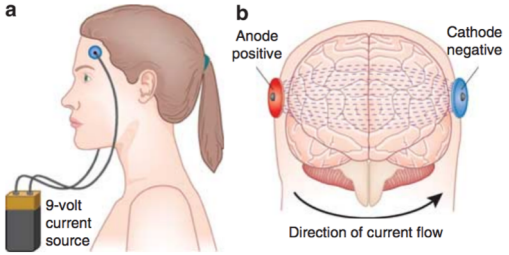
Seed at the body of left hippocampus
Results from 11406 studies
http://neurosynth.org/

Can we improve memory function by modulating hippocampal-cortical memory network?

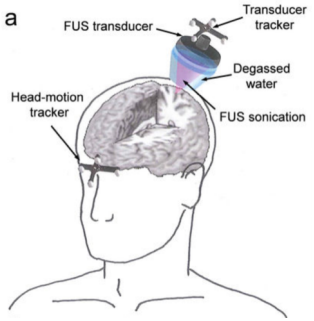
Neuromodulation techniques

How do we modulate brain function?

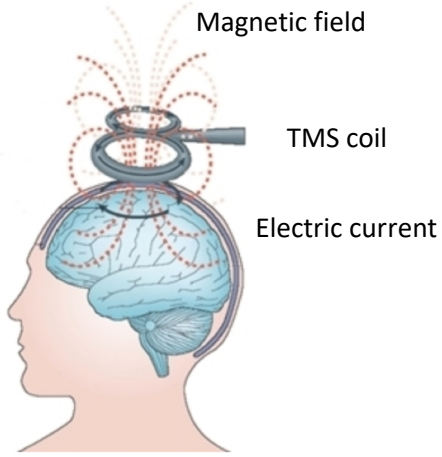
Electrical Stimulation (Non-invasive)



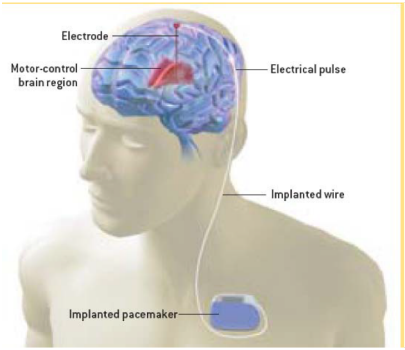
Focused Ultrasound (Non-invasive)



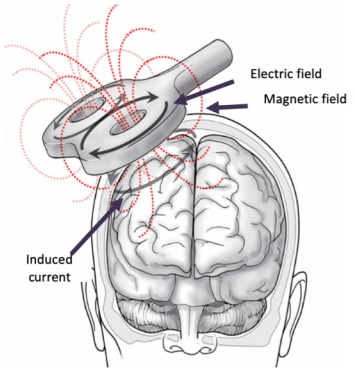
Transcranial Magnetic Stimulation (Non-invasive)

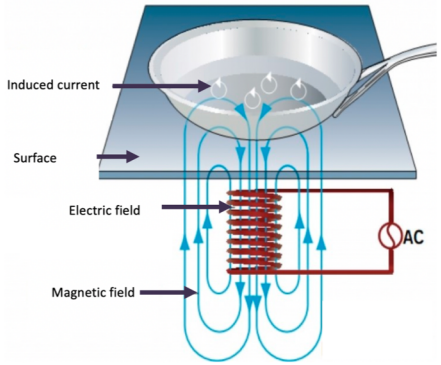


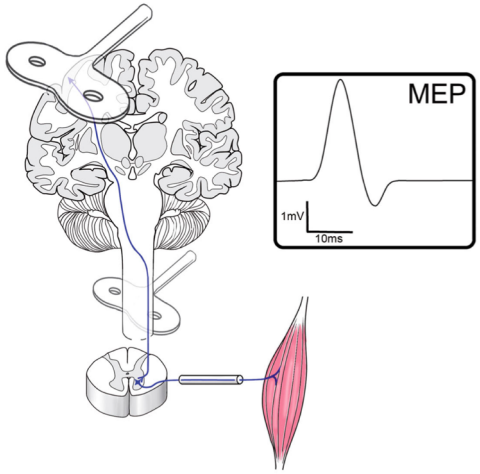
Deep Brain Stimulation (Invasive)



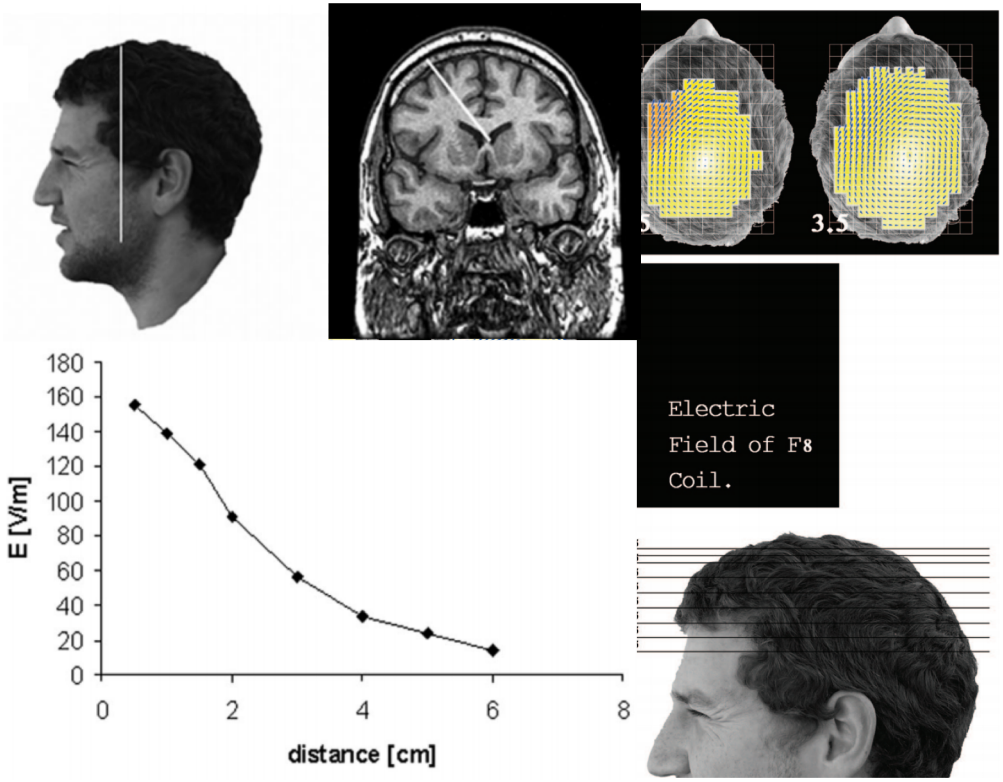
Principle of transcranial magnetic stimulation





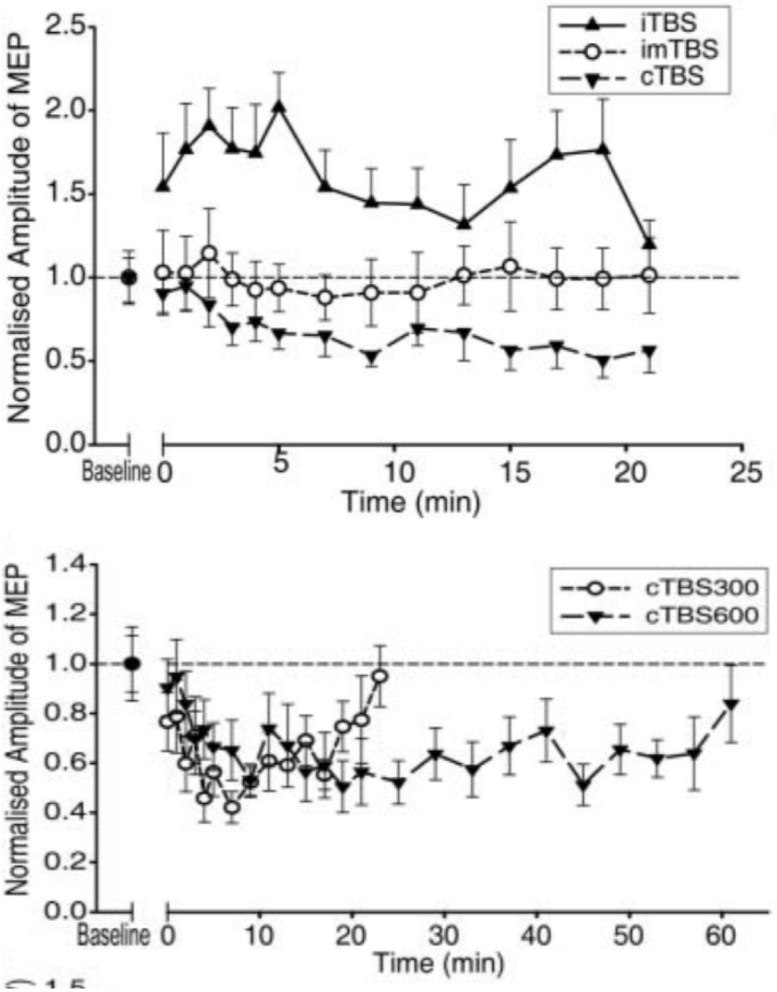


Adapted from Vlachos et al., Neuroforum, 2017

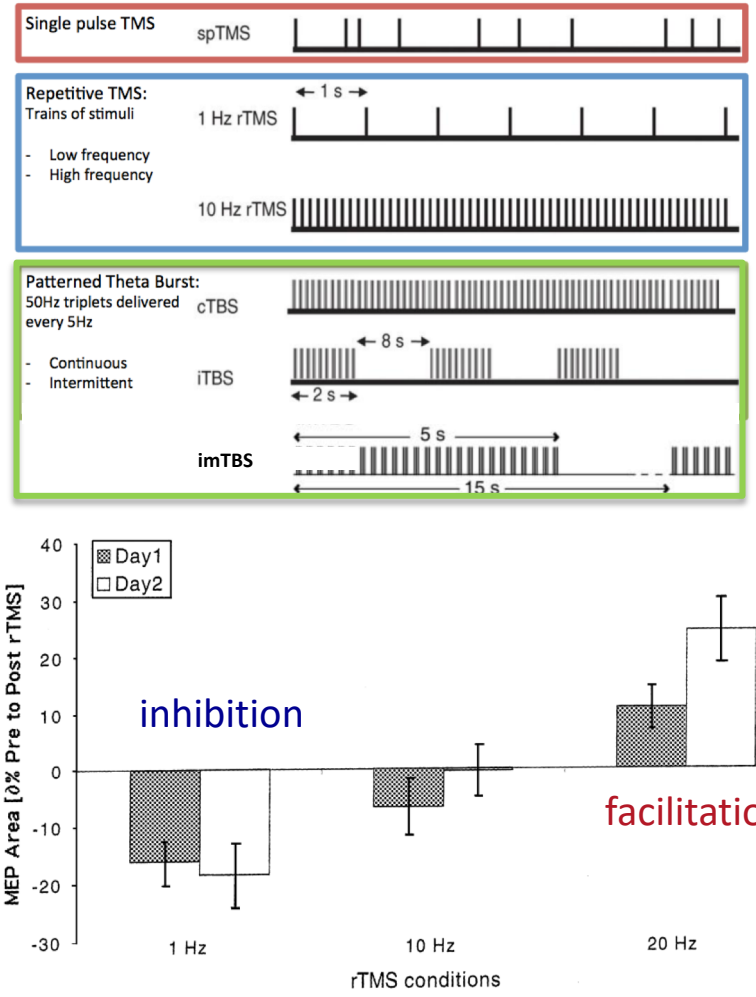


Roth et al., *J Clin Neurophysiol,* 2007

TMS modes



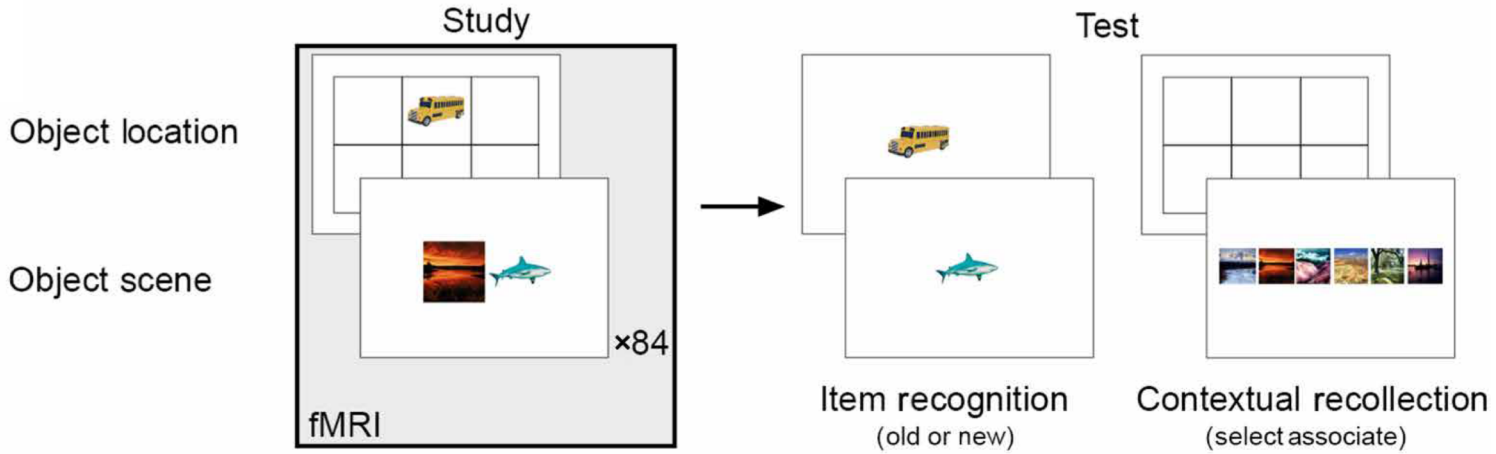
Huang et al., *Neuron,* 2005

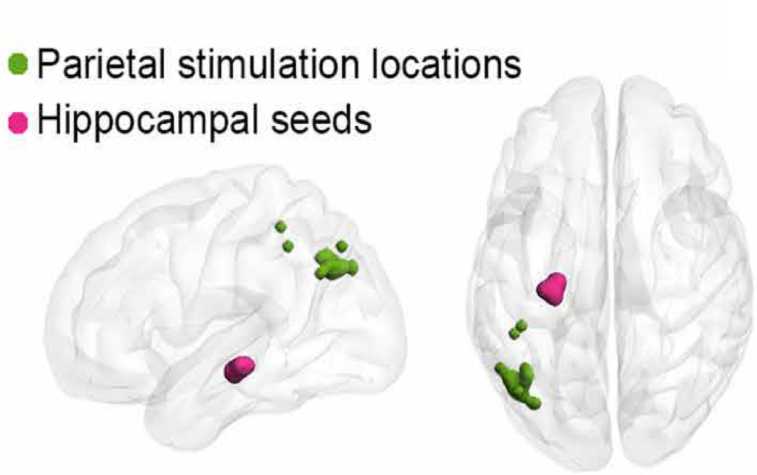


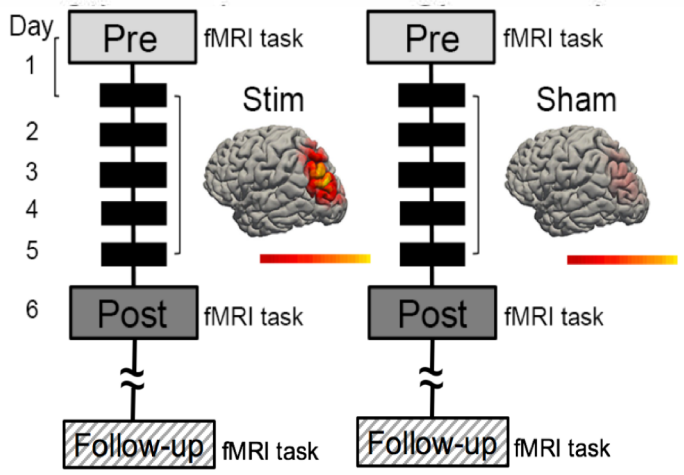
Maeda et al., *Clin Neurophysiol,* 2000

TMS experiment procedure

Selective and coherent activity of episodic memory network



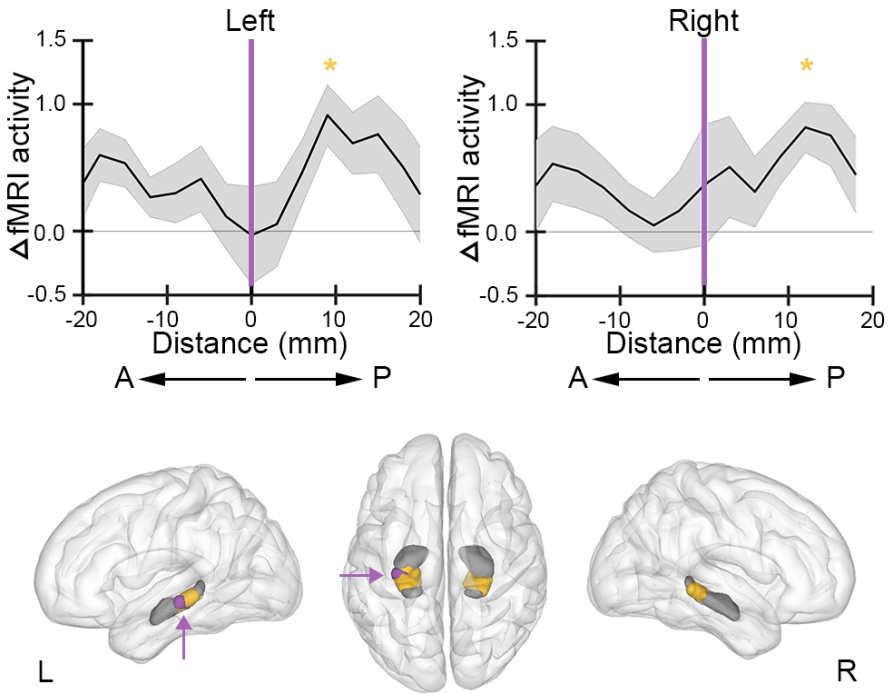




Kim et al., *Science Advances*, 2018

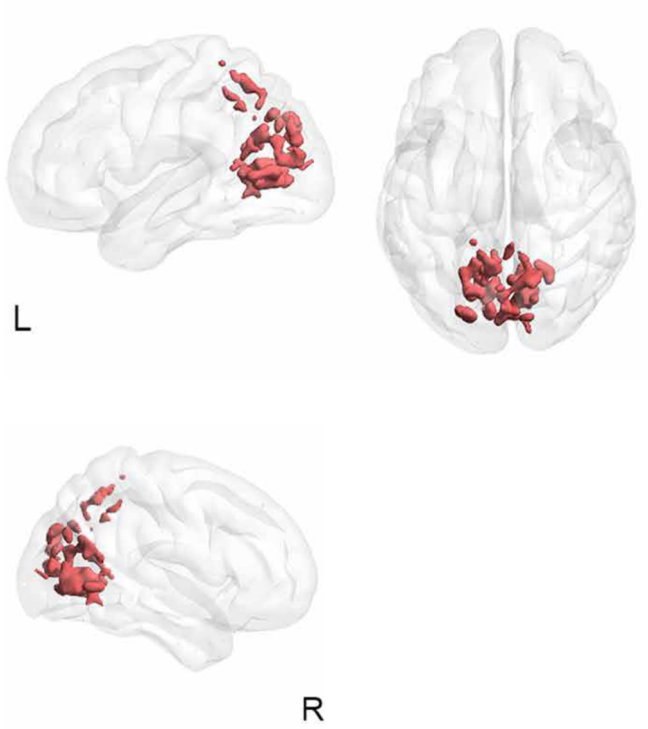
TMS significantly increases activities in hippocampal-cortical networks

Post-Stim > Post-Sham



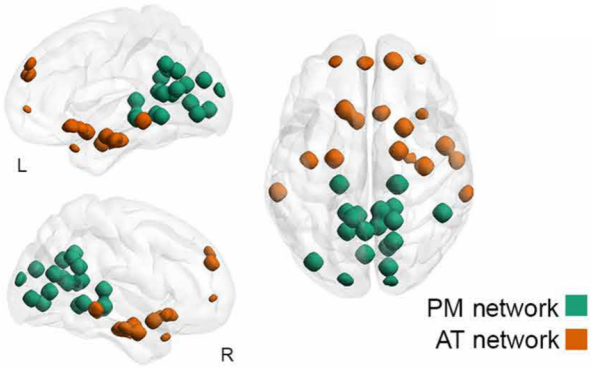
Unpublished data

Post-Stim > Post-Sham



Kim et al., *Science Advances*, 2018

A



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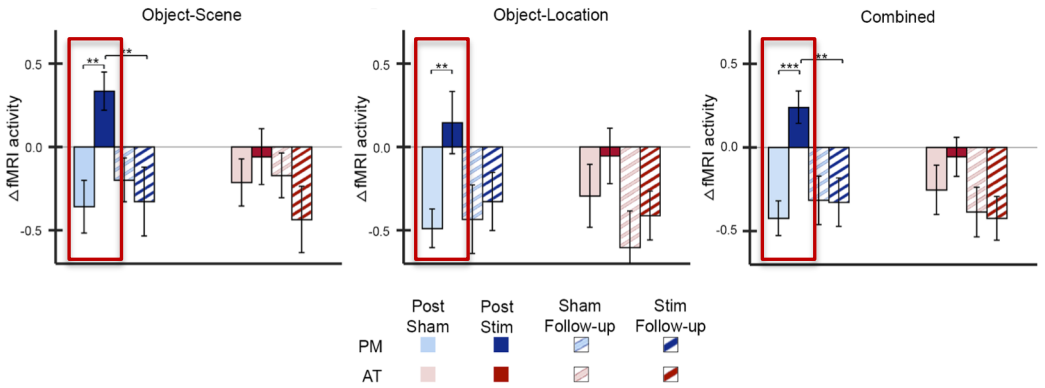
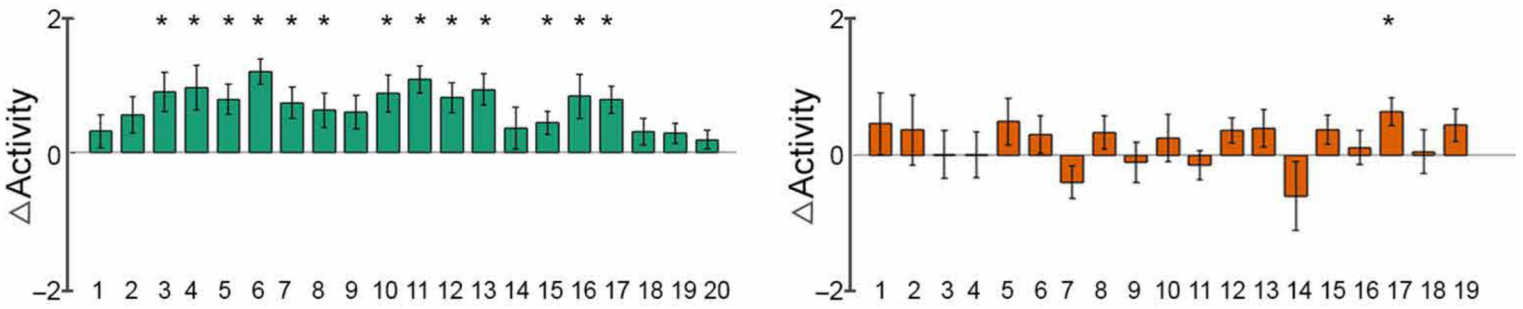
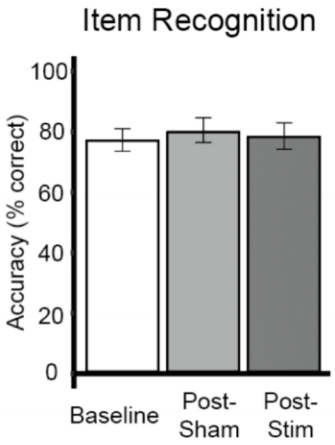


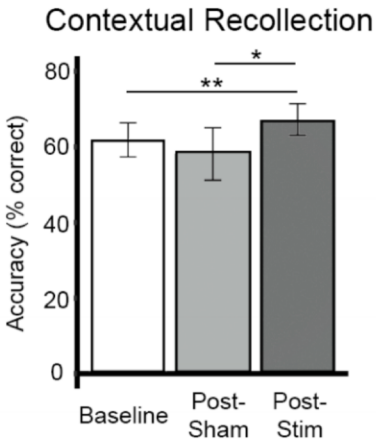
C

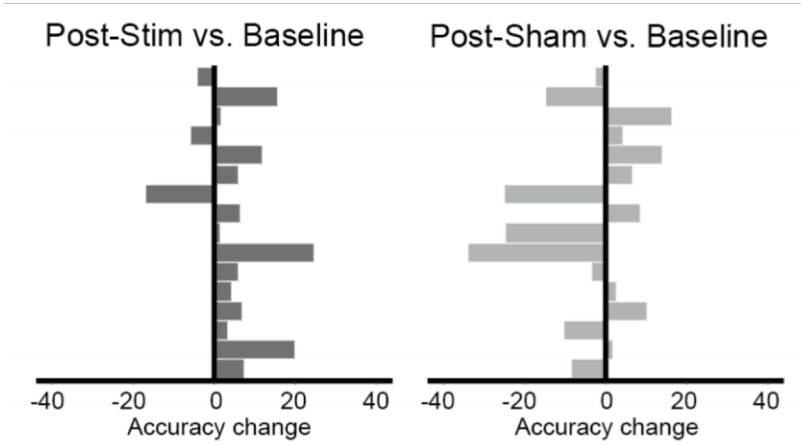


Kim et al., *Science Advances*, 2018

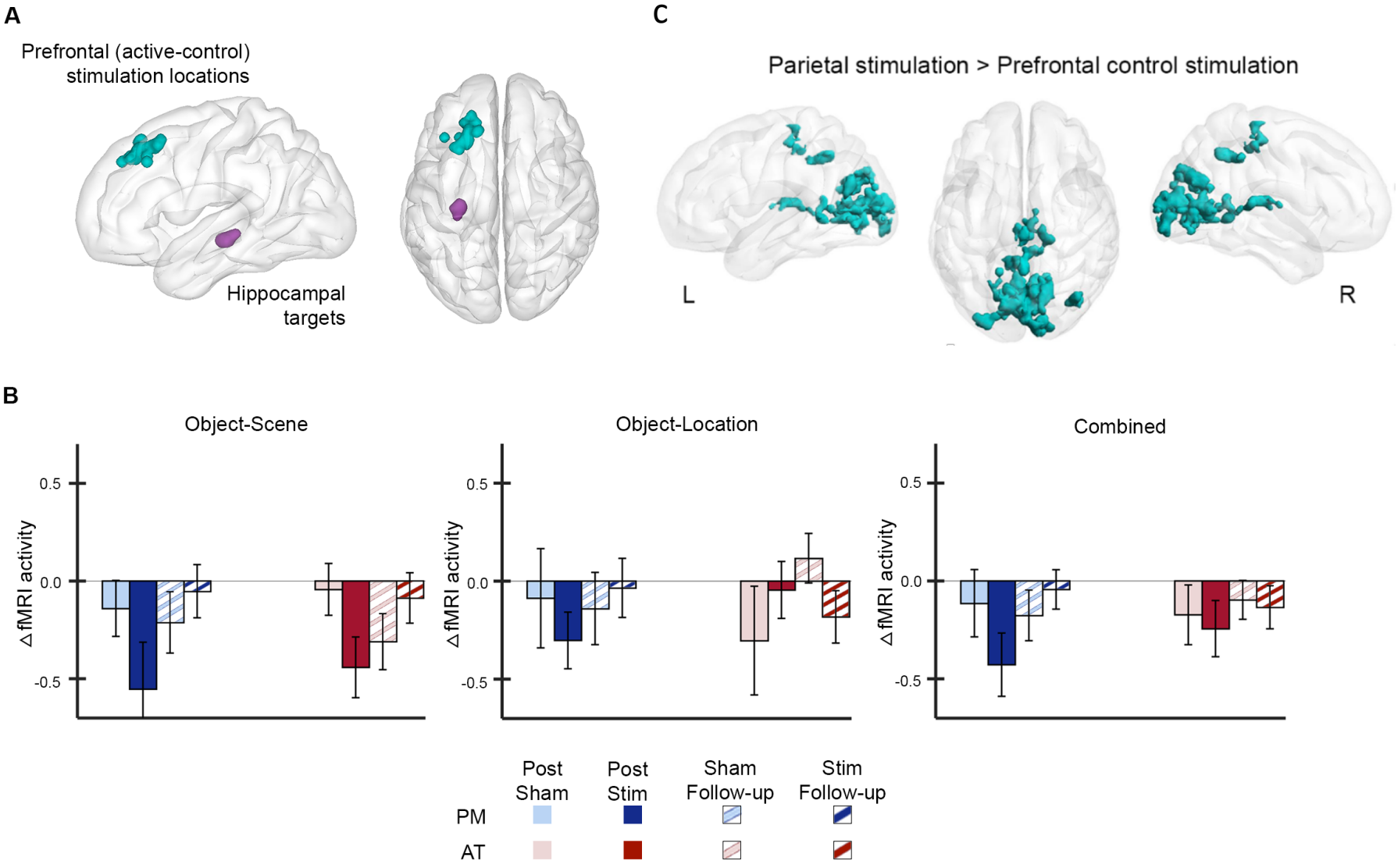
TMS enhances recollection memory accuracy





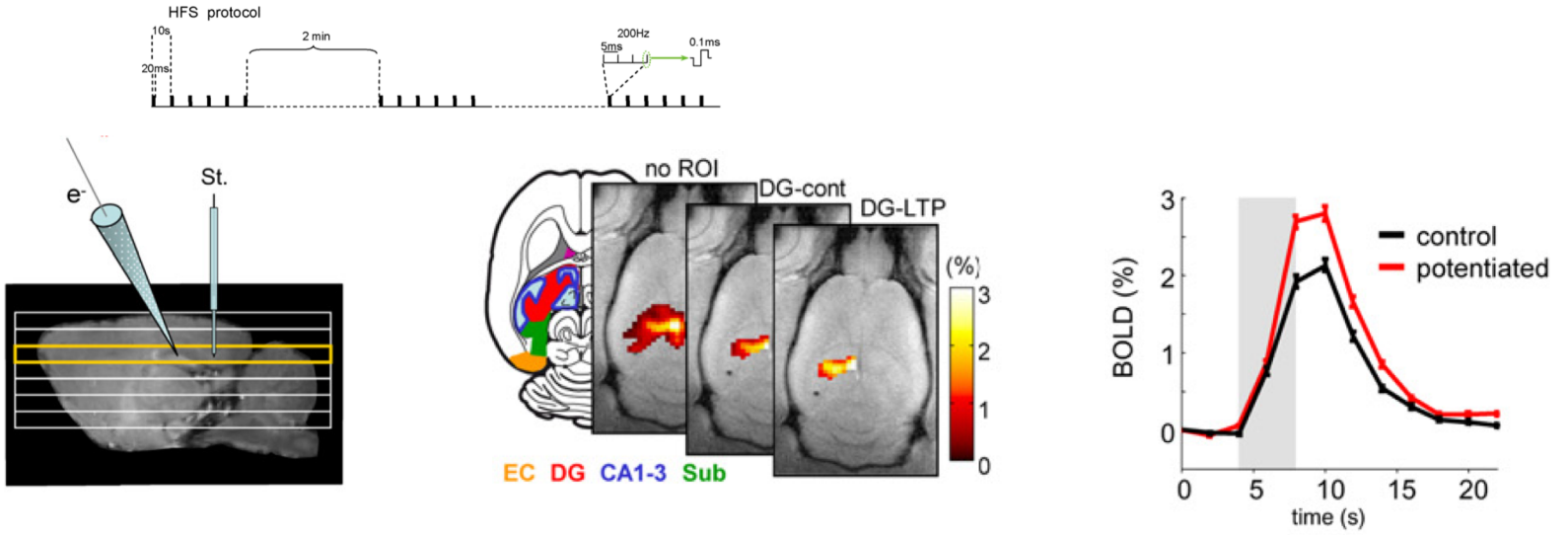


Kim et al., *Science Advances*, 2018



Kim et al., *Science Advances*, 2018

fMRI evidence for LTP-induced neural network reorganization by high frequency electrical stimulation

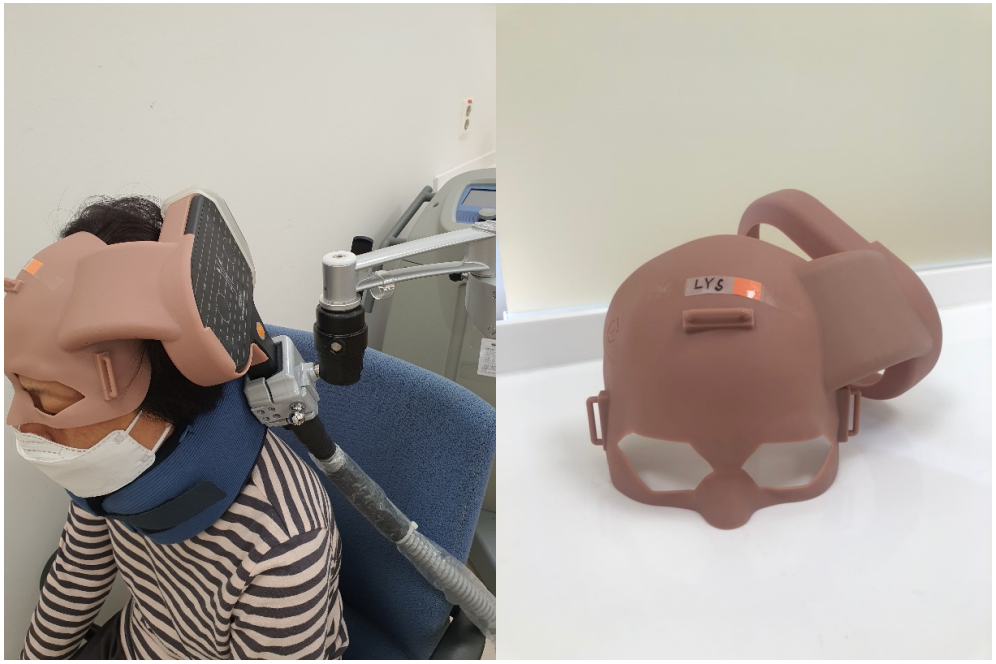


Canals et al., *Current Biology*, 2009

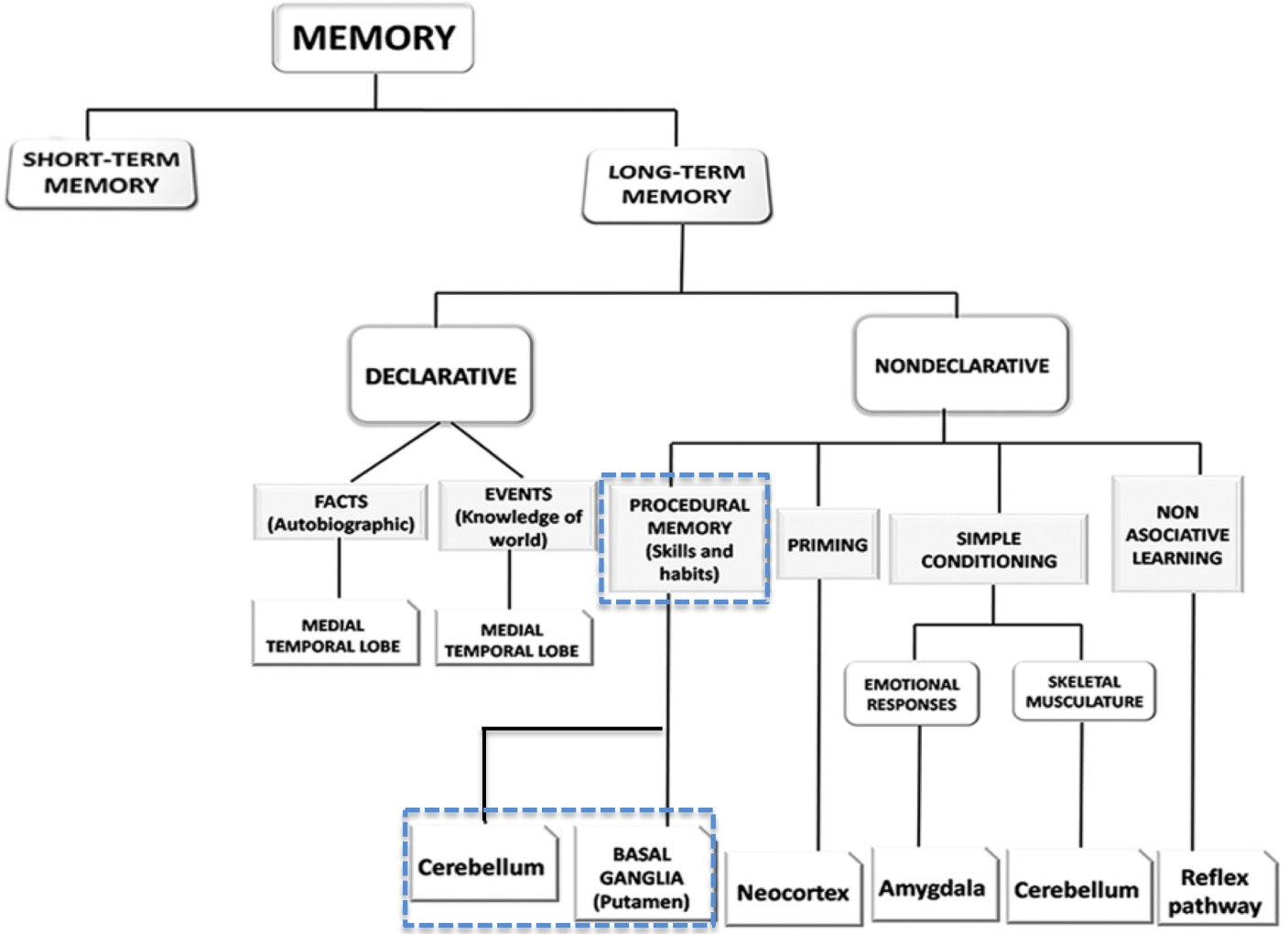
Application of TMS for treatment of early AD and MCI (Mild-cognitive-impairment) patients

REMED, Korea

ANYMEDi
애니메디솔루션



Taxonomy of biological memory

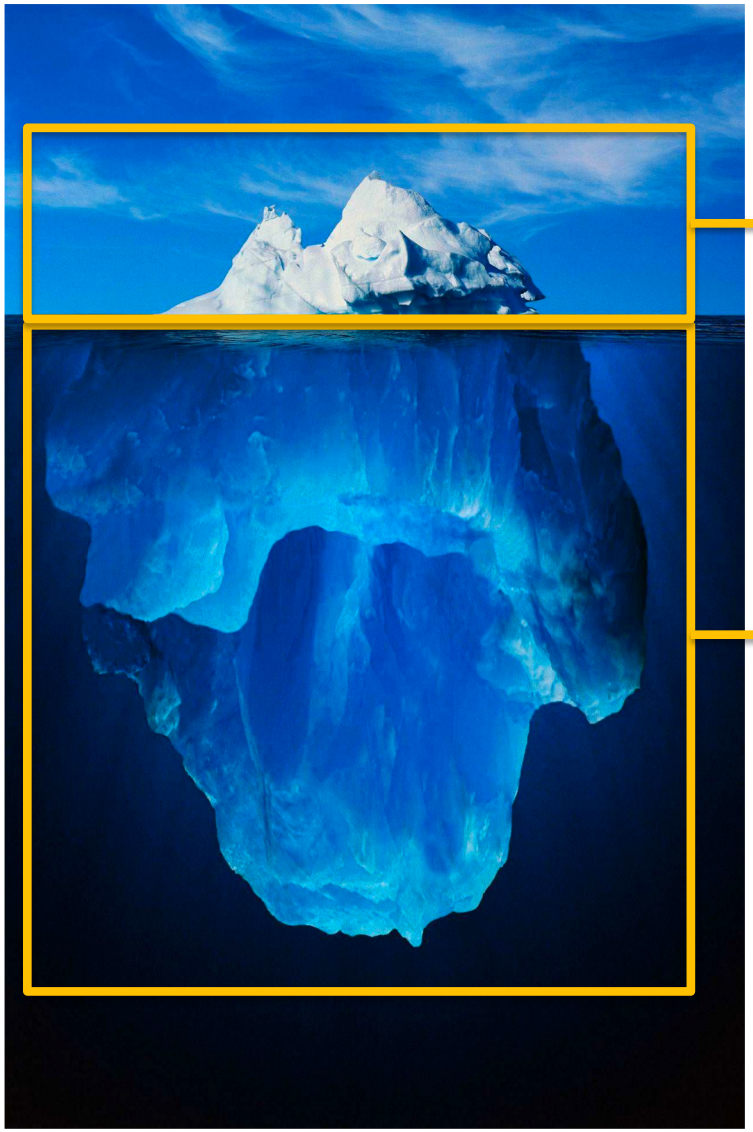


Michael Polanyi

We know more than we can tell

Michael Polanyi (1891-1976)

Tacit knowledge



Explicit (Declarative) knowledge:
tangible, visible, verbalizable

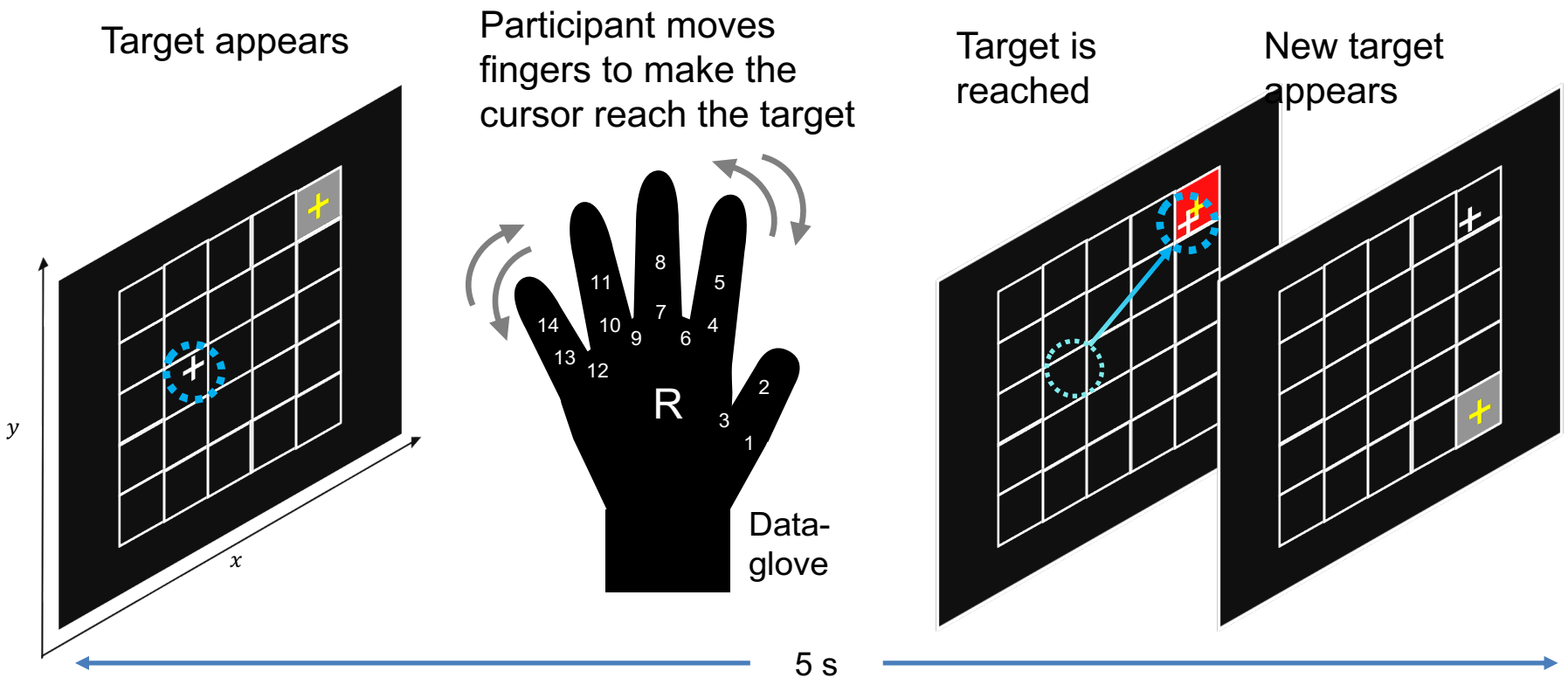
Tacit (implicit, non-declarative) knowledge:
intangible, invisible, inverbalizable

Why motor learning?

Our life is a continuum of motor learning

How do humans acquire new motor skills from scratch?

Experiment Design



$$\begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} a_{x,1} & a_{x,2} & \cdots & a_{x,13} & a_{x,14} \\ a_{y,1} & a_{y,2} & & a_{y,13} & a_{y,14} \end{bmatrix} \times \begin{bmatrix} h_1 & h_2 & \cdots & h_{13} & h_{14} \end{bmatrix}^T + \begin{bmatrix} x_0 \\ y_0 \end{bmatrix}$$

Cursor (designated by)

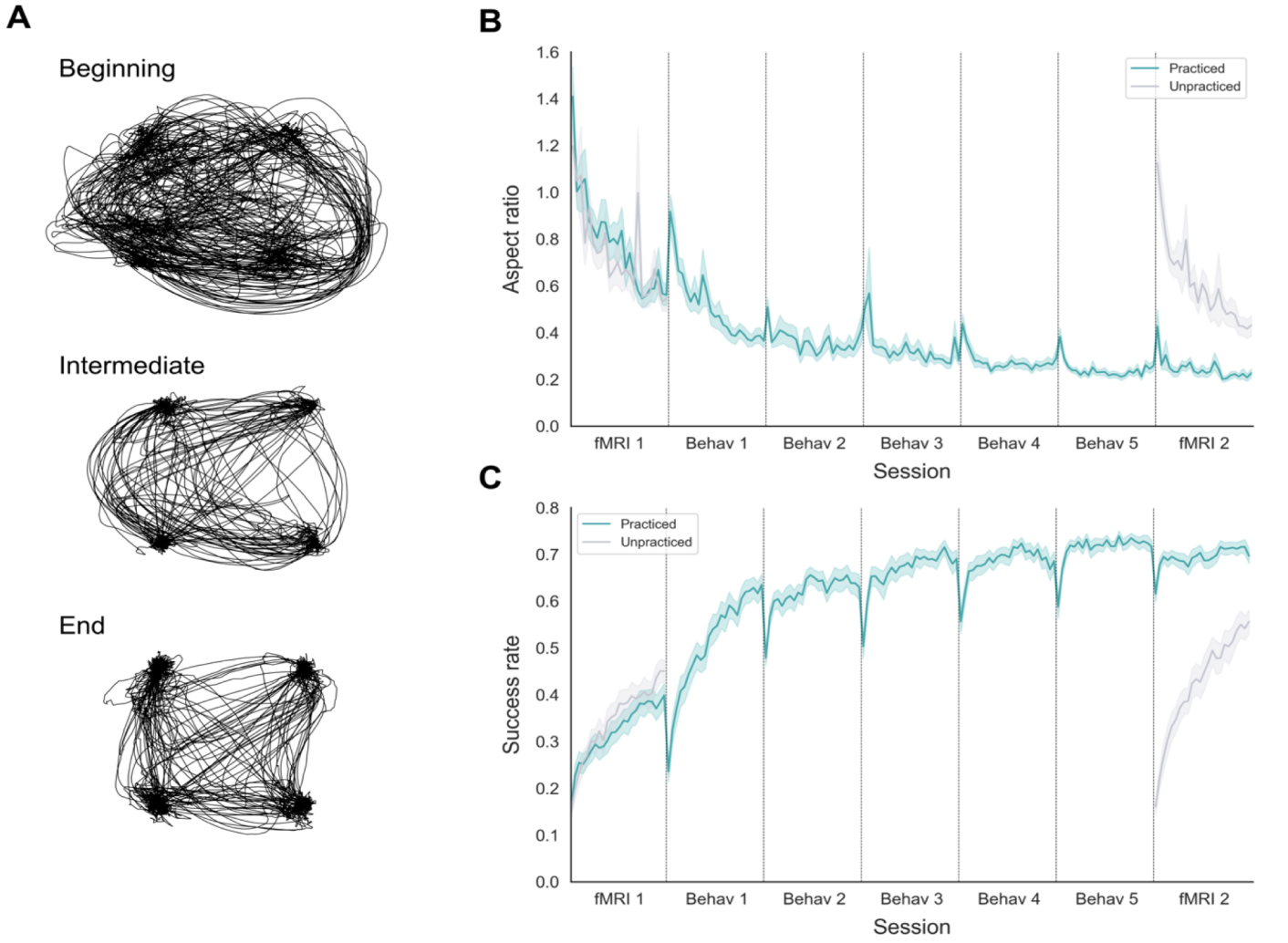
Target (not reached)

Target (reached)

Choi, Shin, and **Kim**, Proc. *Natl. Acad. Sci.*, 2020

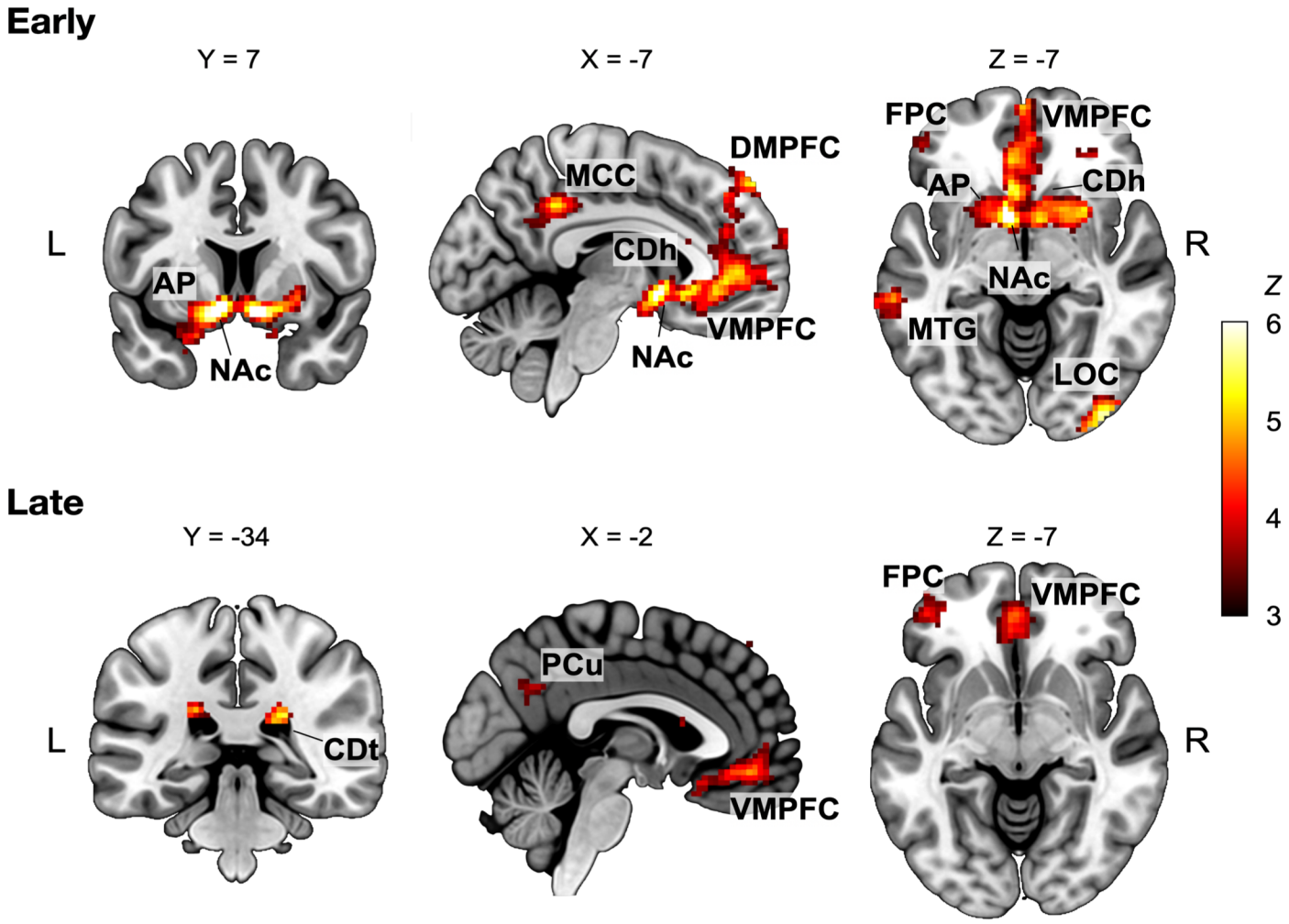
변화하는 인간
호모 사이언스

Improvement of motor skills



Choi, Shin, and **Kim**, Proc. *Natl. Acad. Sci.,* 2020

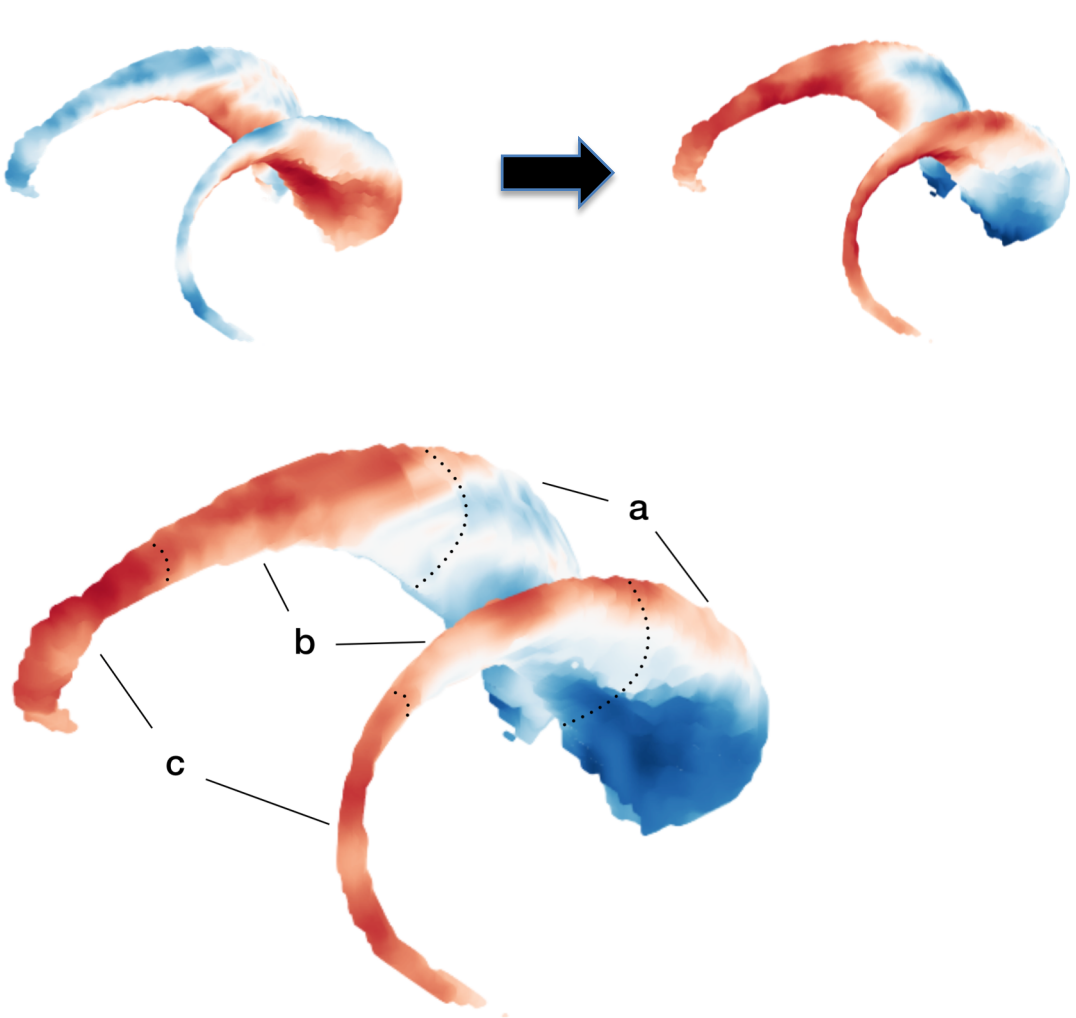
Neural co₩rrelates of reward modulation in early and late stage of learning

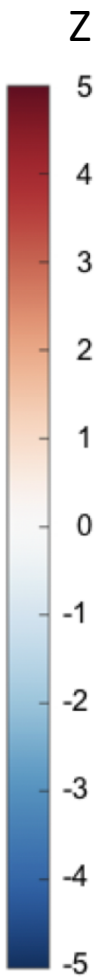


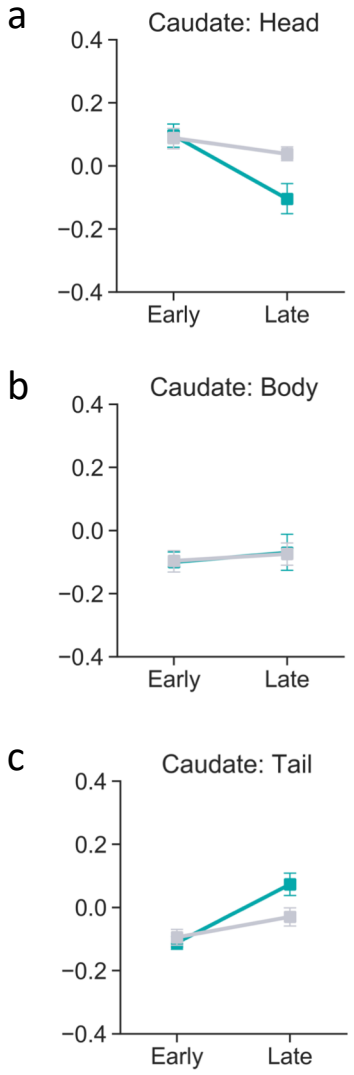
**Voxel-wise p < 0.001, corrected p < 0.05*

Choi et al, Proc. *Natl. Acad. Sci.,* 2020

Gradual transition of reward modulation in the caudate nucleus

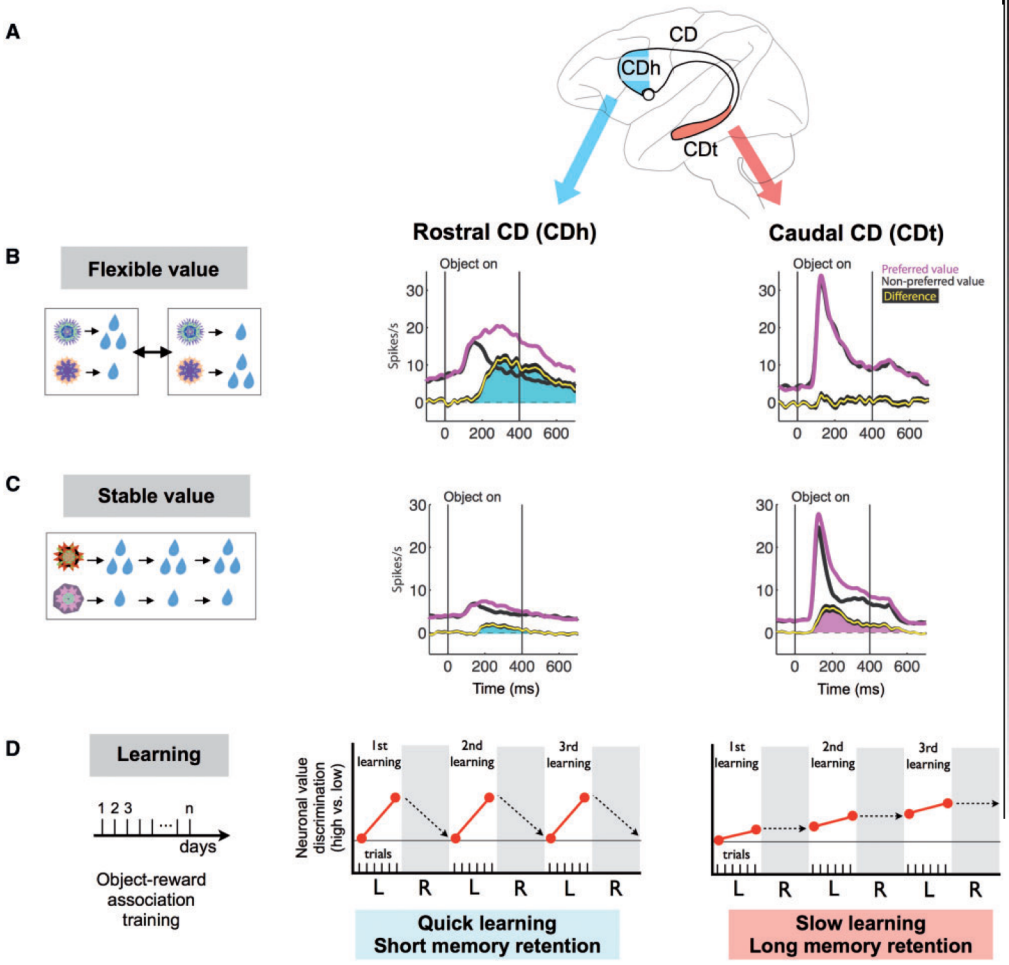


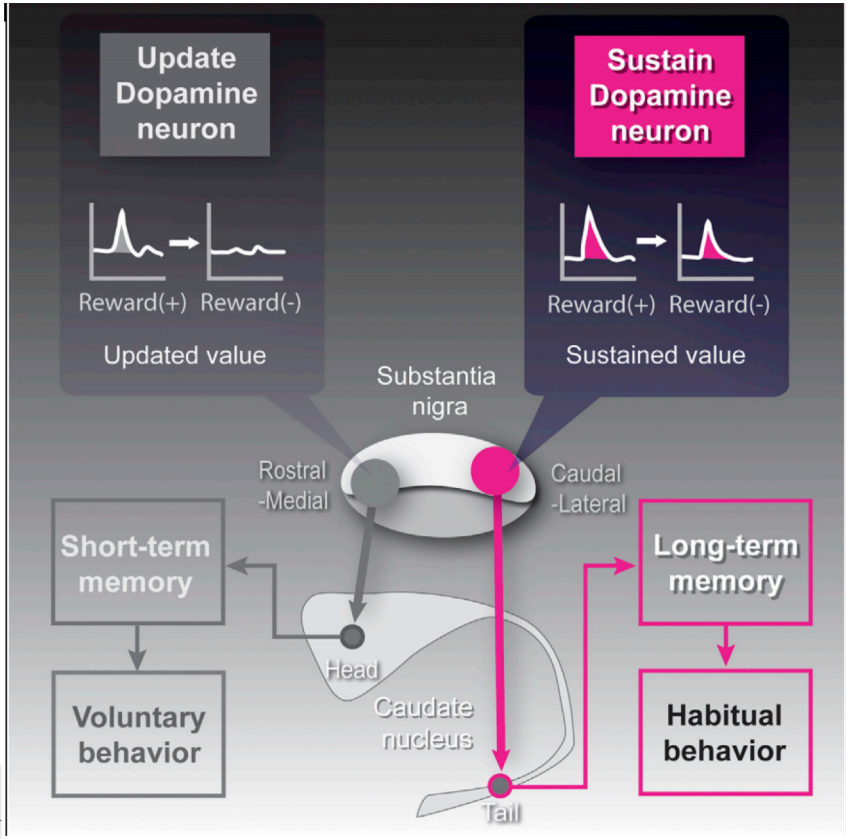




Choi, Shin, and **Kim**, Proc. *Natl. Acad. Sci.,* 2020

NHP studies identified parallel circuits in the caudate nucleus for object skill learning

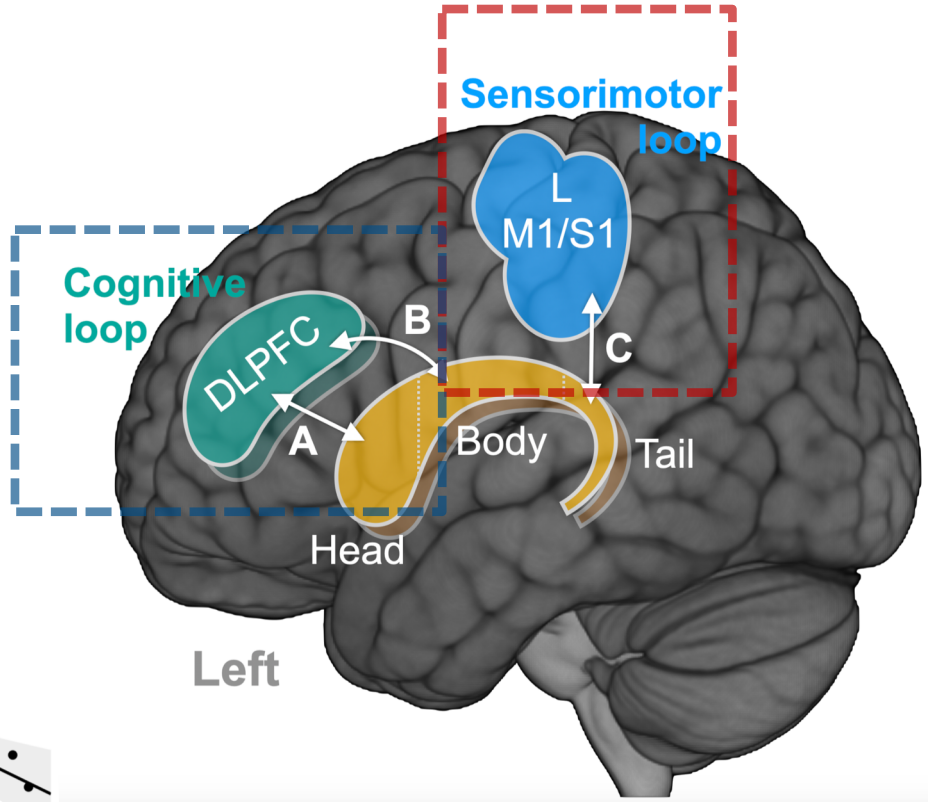


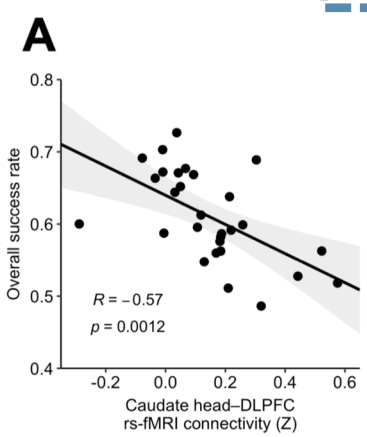


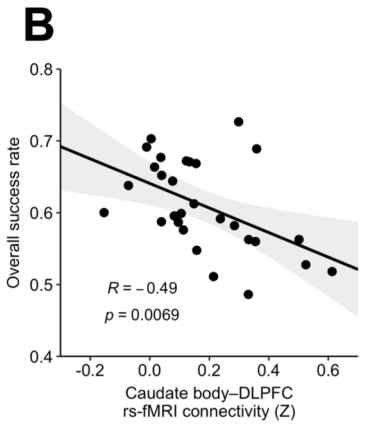
HF Kim, AG Ghazizadeh, O Hikosaka, *Cell*, 2015

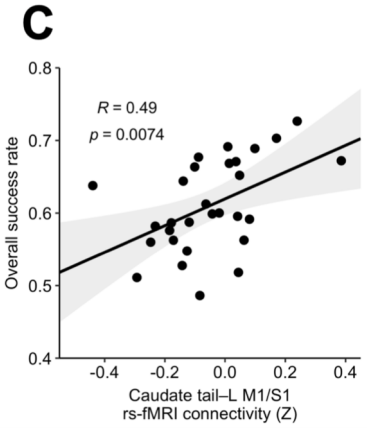
HF Kim and O Hikosaka, *Brain*, 2015

Cortical-caudate interactions predict individual learning performance



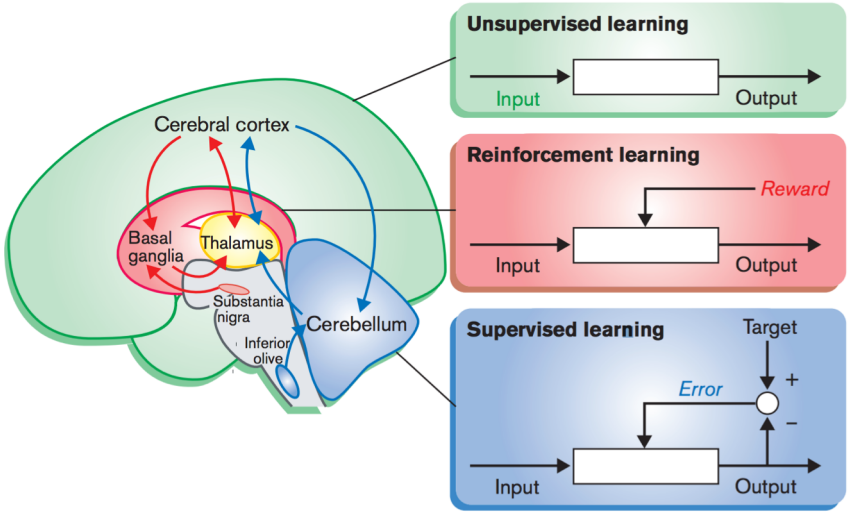






Choi, Shin, and **Kim**, Proc. *Natl. Acad. Sci.*, 2020

Conclusion: Complementary memory systems



Doya, *Curr Opinion Neurobiol*, 2000

Neocortex

Replay

Hippocampus

Kumaran et al., *Trend. Cogn. Sci.*, 2016

Key Questions

1. **Strong AI:** How can human brains generalize learning across multiple tasks?
2. **Efficiency of the brain:** How can human brains learn from very few samples?
3. **Augmented learning:** How can noninvasive brain stimulation (e.g., TMS) enhance learning?

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