Lifelong Learning Across Synapses, Circuits, and Brain Areas

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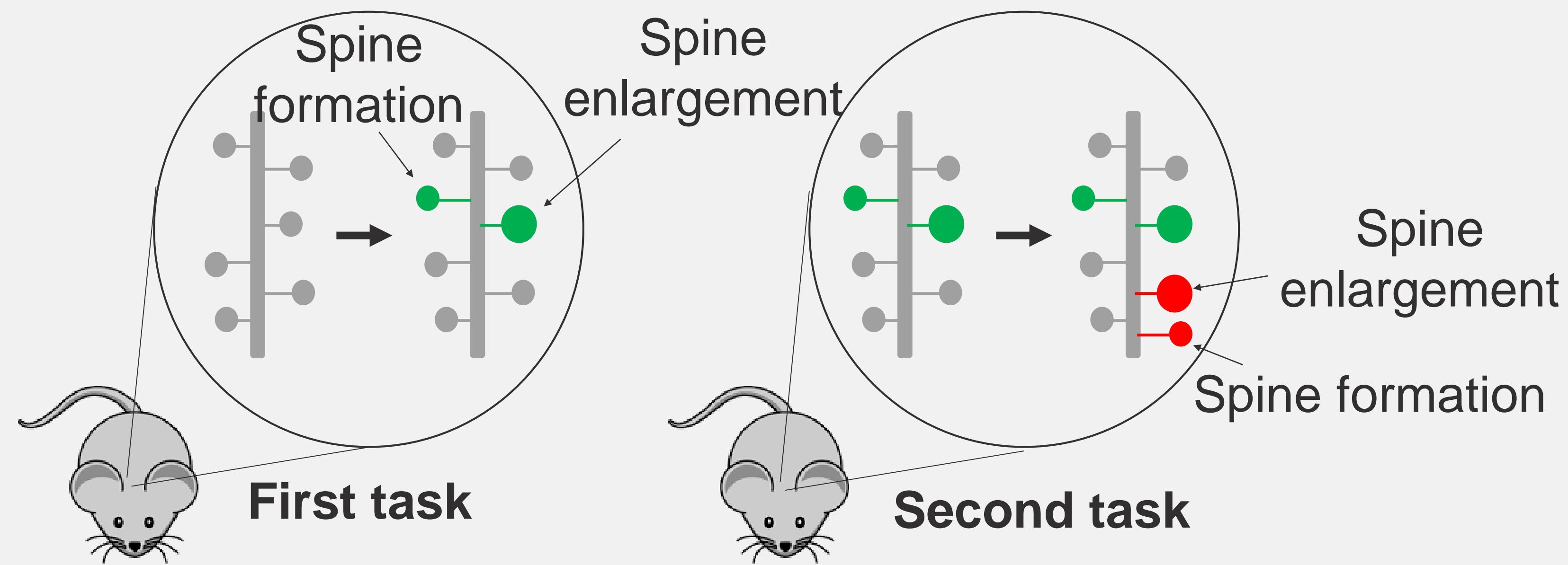
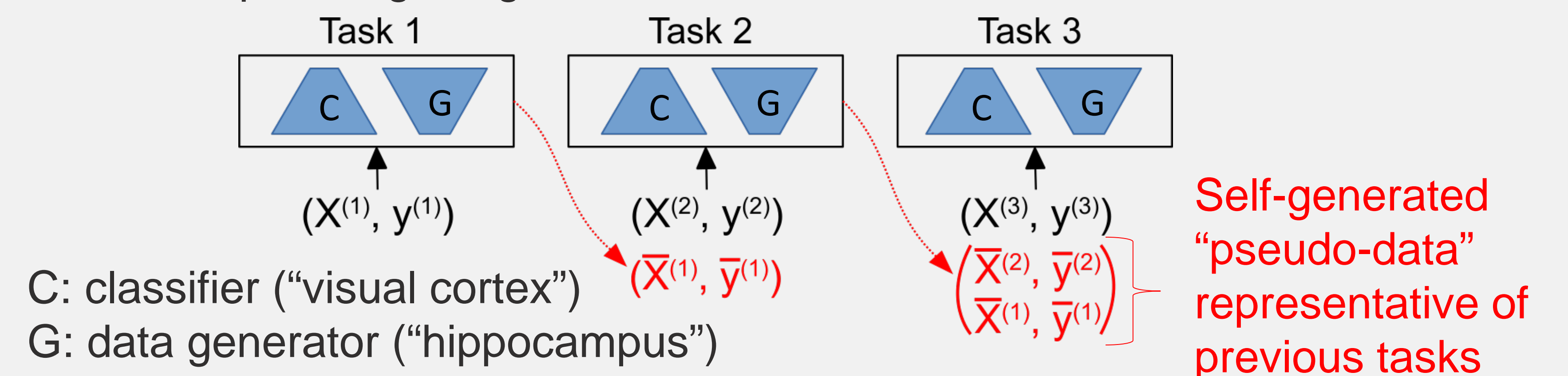## Specialized Functions: Lifelong Learning Machines (L2M)

Overview

This work attempts to test learning models against observed physiological responses in real neurologic synapses

Hypothesis 1: Dendritic spines are remodeled as animal trains on a task

Spine formation
Spine enlargement
Spine enlargement
Spine formation
First task
Second task

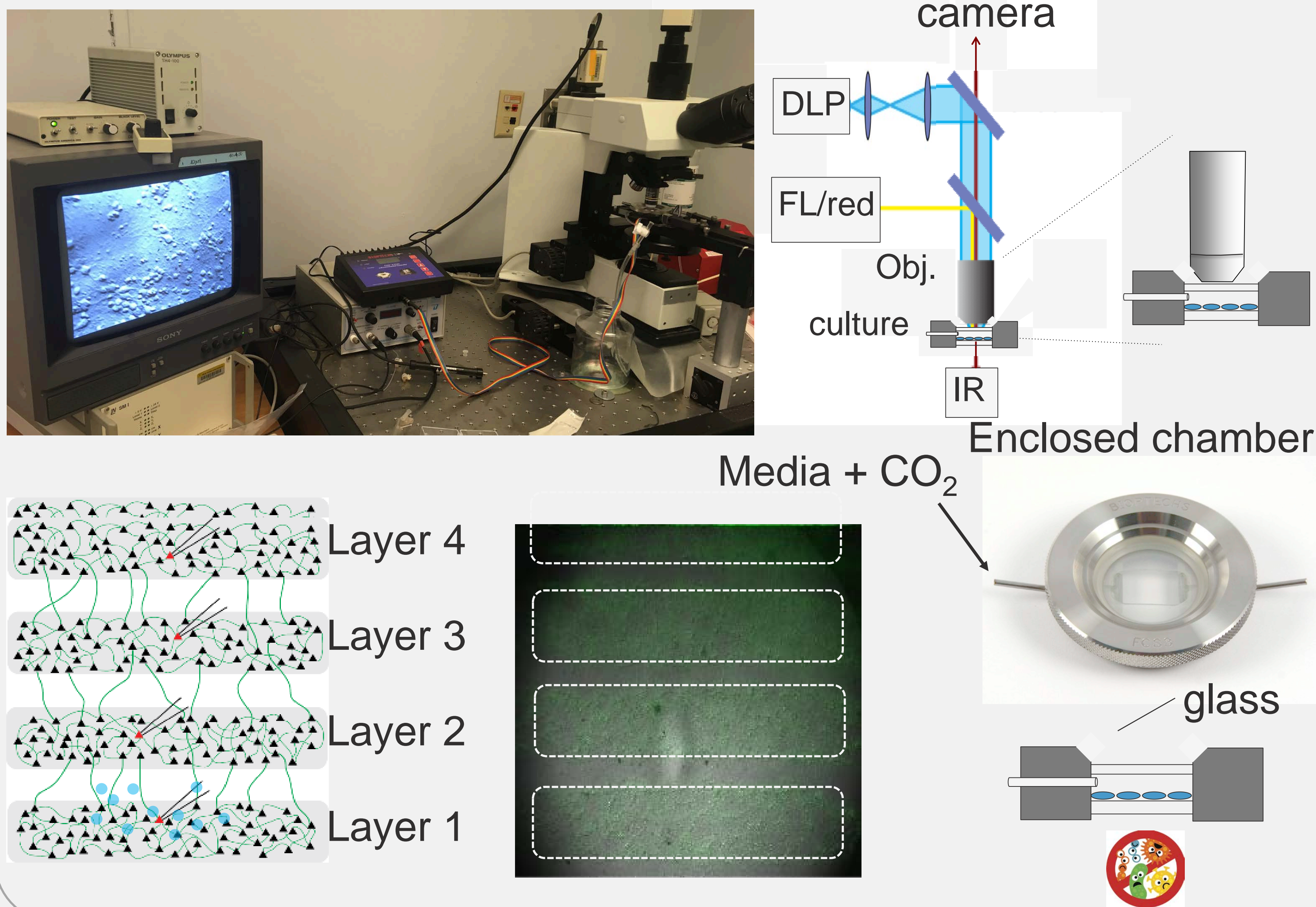source of mouse cartoon: http://www.clkan.com

Hypothesis 2: Memories are strengthened as they are replayed across brain areas

Can memory replay from a generative model reduce catastrophic forgetting in artificial neural networks?
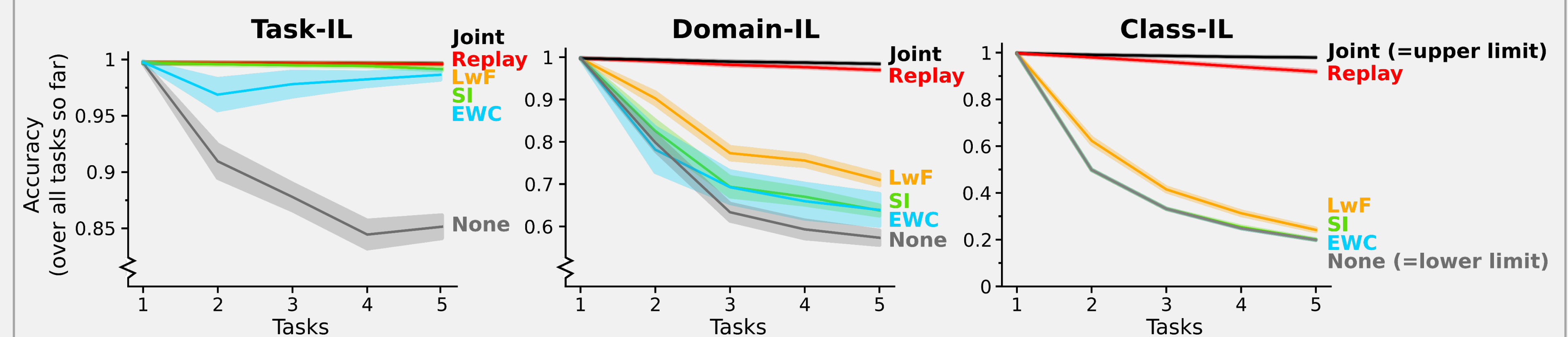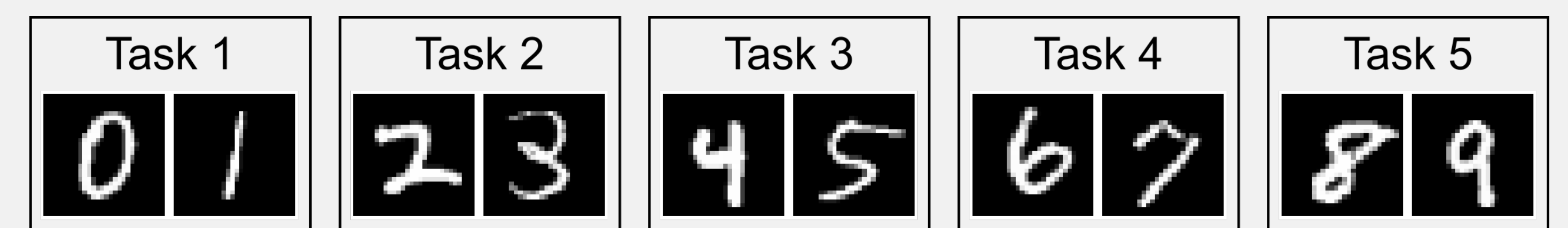

Task 1 C G $(X^{(1)}, y^{(1)})$
Task 2 C G $(X^{(2)}, y^{(2)})$ $(\overline{X}^{(1)}, \overline{y}^{(1)})$
Task 3 C G $(X^{(3)}, y^{(3)})$ $\left(\overline{X}^{(2)}, \overline{y}^{(2)}\right)$ $\left(\overline{X}^{(1)}, \overline{y}^{(1)}\right)$

C: classifier ("visual cortex")
G: data generator ("hippocampus")

Self-generated "pseudo-data" representative of previous tasks

Experimental: Approach / Results

Optically stimulate synapse and record photo-optic response in cultured neuronal networks

camera
DLP
FL/red
Obj.
culture
IR
Enclosed chamber
Media + CO_2
glass

Layer 4
Layer 3
Layer 2
Layer 1

Modeling: Approach / Results

Split MNIST:

Task 1 — 0 1
Task 2 — 2 3
Task 3 — 4 5
Task 4 — 6 7
Task 5 — 8 9

Task-IL — Joint, Replay, LwF, SI, EWC, None
Domain-IL — Joint, Replay, LwF, SI, EWC, None
Class-IL — Joint (=upper limit), Replay, LwF, SI, EWC, None (=lower limit)

Accuracy (over all tasks so far) — Tasks

*Existing methods (SI, EWC & LwF) can do Incremental Learning (IL) of multiple tasks when task identity is provided ("Tasks-IL"), but they struggle when task identity is not provided ("Domain-IL") and they completely fail when task identity needs to be inferred ("Class-IL"). **Generative Replay** performs well in all scenarios. (Higher is better in these plots.)*
→ ***Can these forms of learning be observed in the physiologic measurements on the left?***

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