Spaun and the Nengo Neural Simulator

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What is it?

- *Spaun* is a 2.5 million neuron model of the brain that is able to capture and demonstrate complex behavior
- At the time of release (2012), it was the world's largest functional model
- The seminal paper demonstrated success on 8 diverse tasks

How?

- This is a large-scale spiking neuron model, meaning it is similar to what we have studied but larger in scale
- *Spaun* was developed with *Nengo*; a graphical and scripting based software package for simulating large-scale neural systems (using Neural Engineering Framework)

Who?

Figure 1: Chris Eliasmith, Ph.D

UNIVERSITY OF WATERLOO

Figure 2: University of Waterloo

- Paper published in 2012.
- *A large-scale model of the functioning brain.* [1]

Spaun (Semantic Pointer Architecture Unified Network)

- Video introduction: `https://youtu.be/P_WRCyNQ9KY`

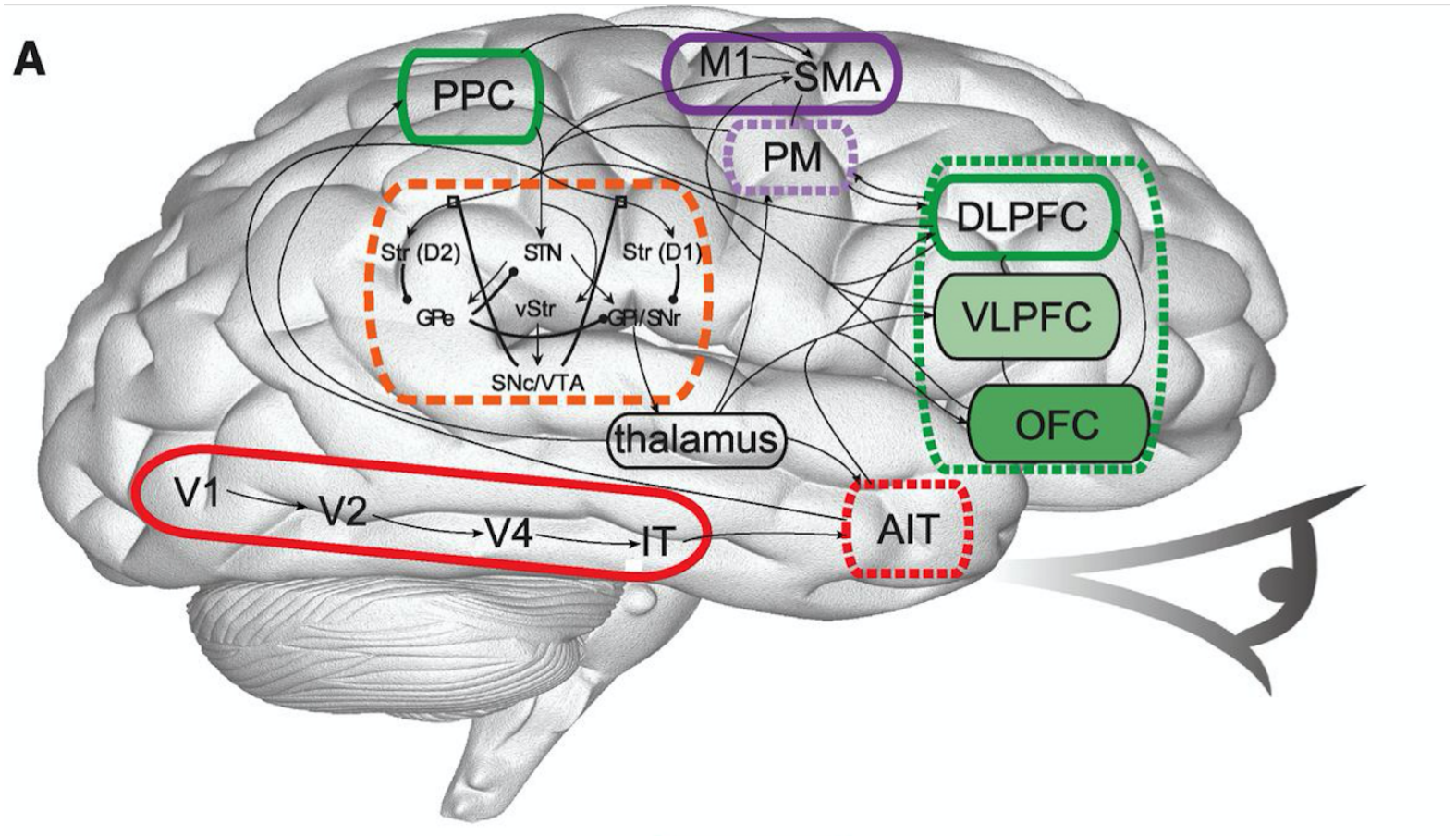

Figure 3: Spaun Architecture

Architecture Hierarchy

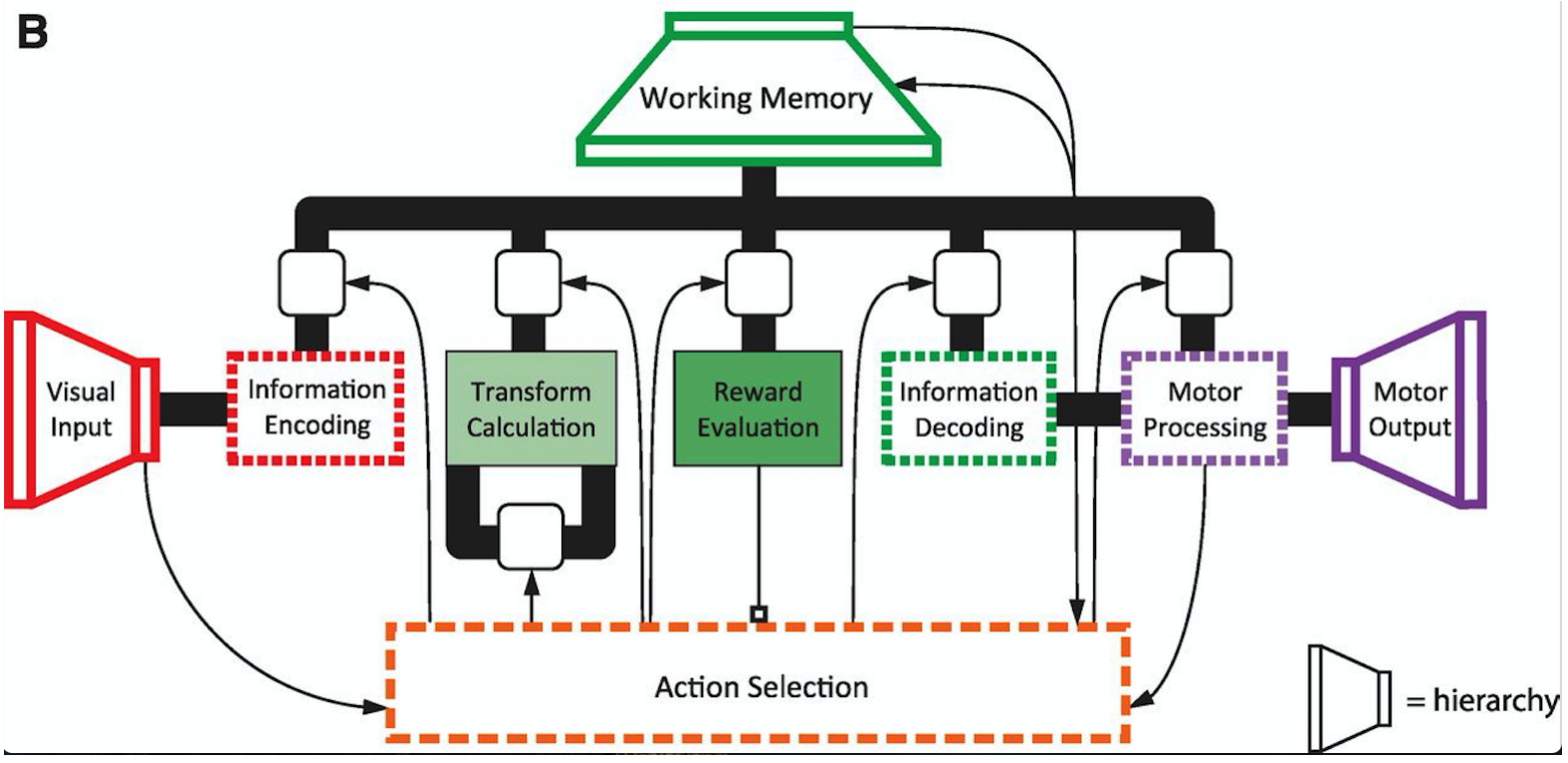

Figure 4: The Spaun architecture's hierarchical design.

Nengo

- "Nengo is a graphical and scripting based software package for simulating large-scale neural systems."
- Essentially, it works by defining groups of neural activity and relating those groups by computations that will be done on those representations.
- Nengo utilizes the Neural Engineering Framework for learning the synaptic weights; a framework developed by Waterloo for building biologically plausible neural circuits.
- Example Nengo video: `https://www.youtube.com/watch?v=UVeIPKnQAL4`
- pip install nengo
- pip install nengo_gui

So what can Spaun do?

Performs Functional Action

Spaun has been shown to perform well on 8 different tasks. Those tasks are....

1. Copy Drawing Style
2. Image Recognition
3. Reinforcement Learning
4. Serial Working Memory (List Memory)
5. Counting
6. Question Answering: With list, what is at position x, and what position is x at?
7. Rapid Variable Creation (novel pattern generation)
8. Fluid Reasoning (semantic pattern completion)

What's the input?

- Spaun's input only consists of images
- Flashed at 150 ms intervals for 150 ms each
- Alerted of task by A and number (0-7)
- Perception limited to digits 0-9

Copy Drawing Style

- A picture is given to Spaun, and it must draw the number that was presented in a similar style.

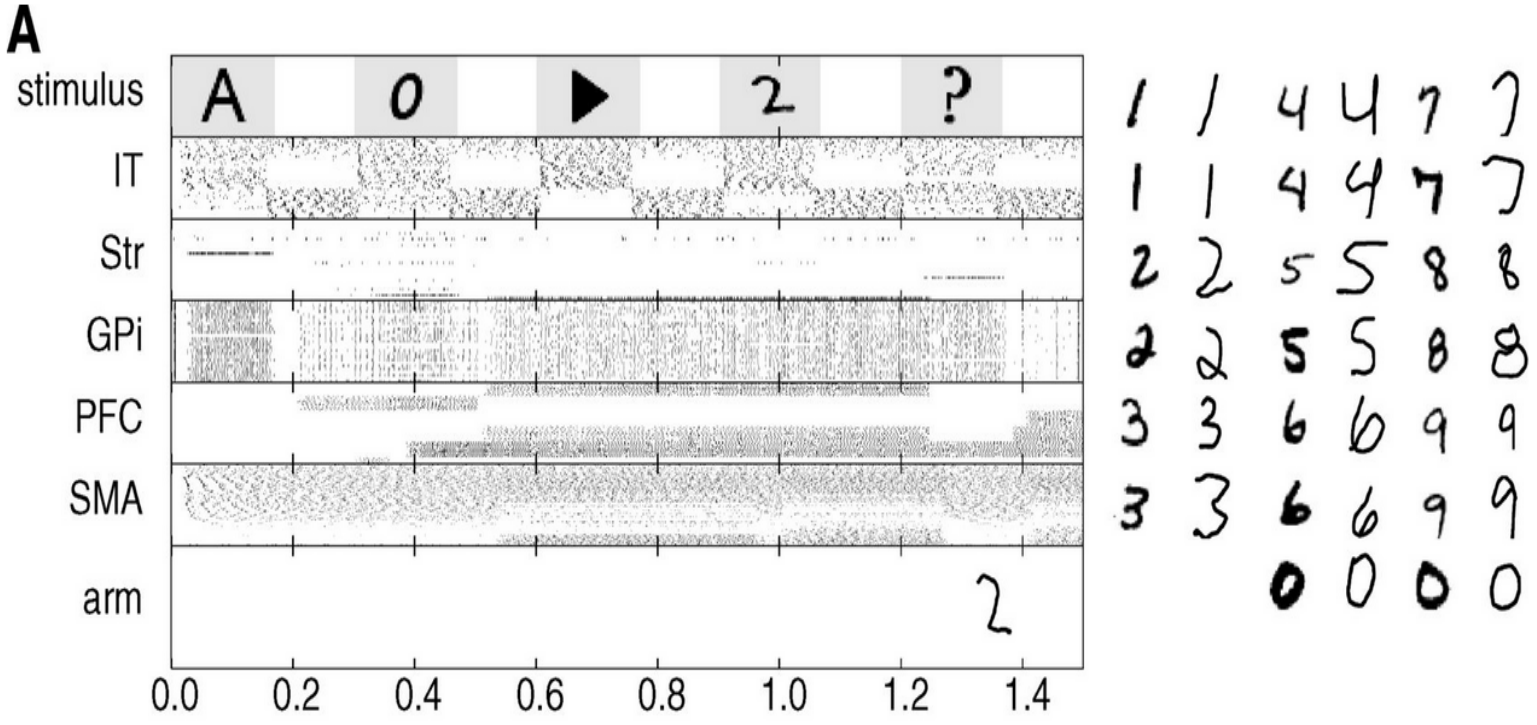

Figure 5: https://www.youtube.com/watch?v=WNnMhF7rnYo

Image Recognition (94%)

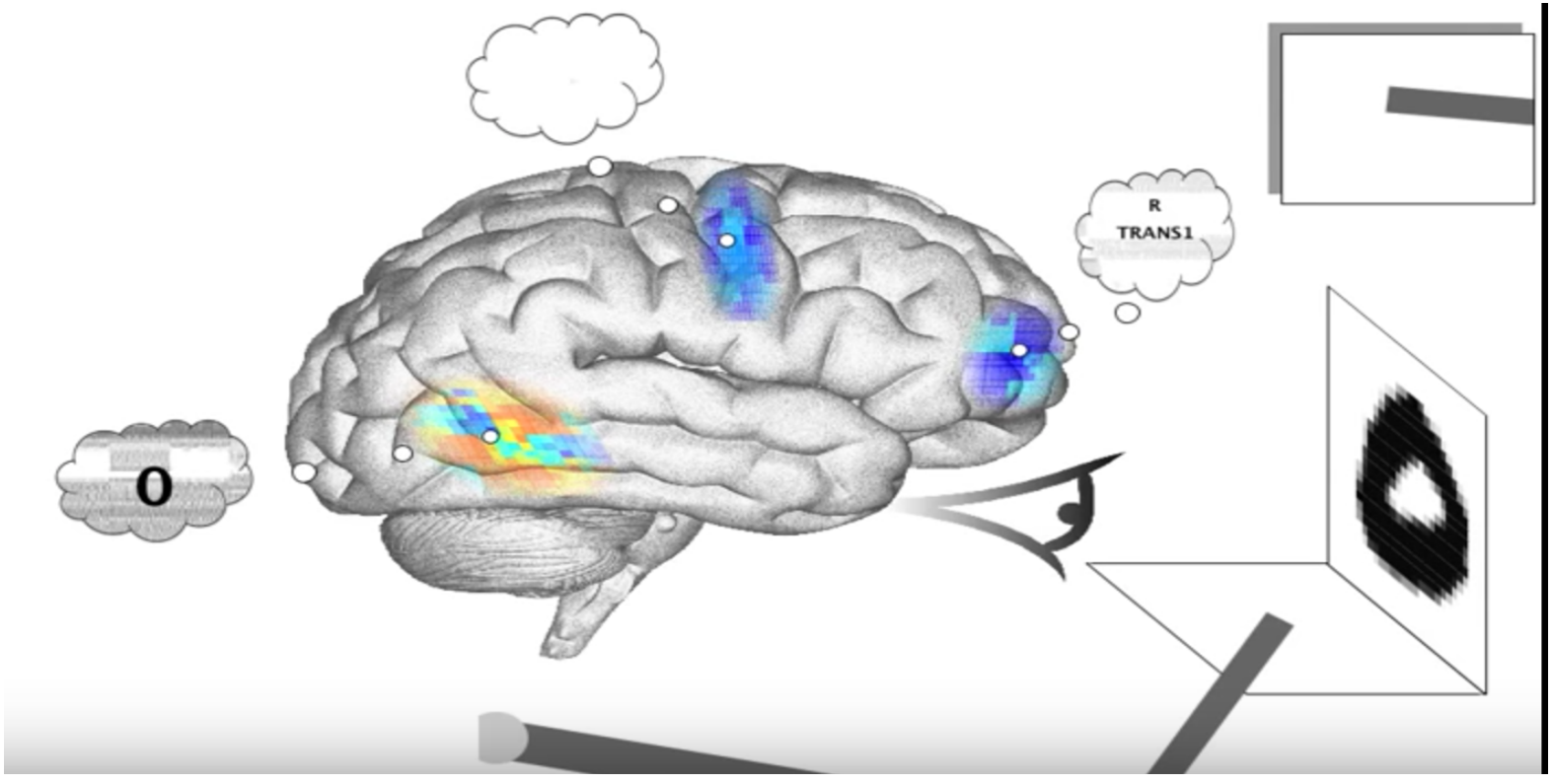

Figure 6: Digit input

Image Recognition (94%)

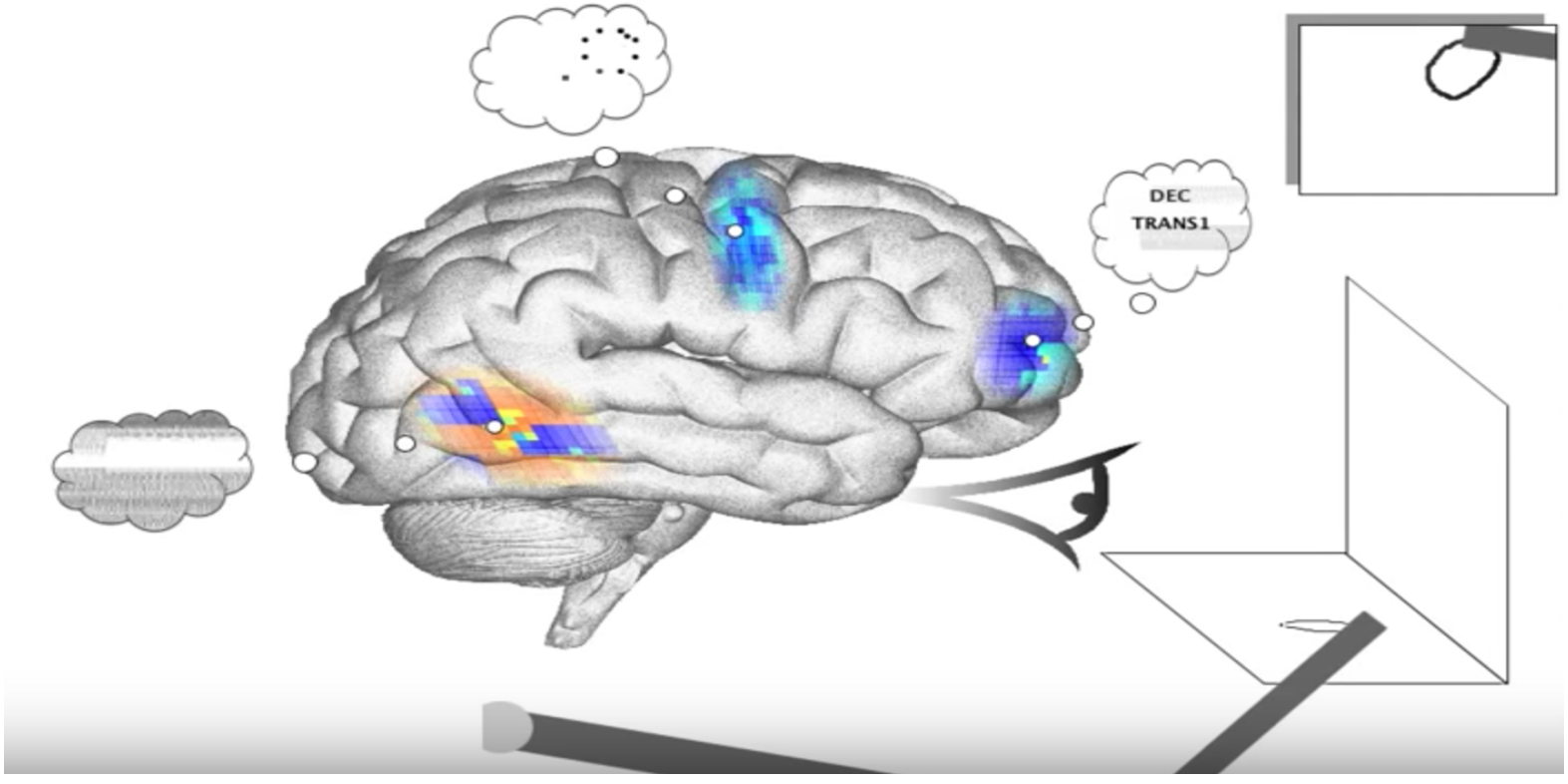

Figure 7: Recognized digit drawing

Reinforcement Learning

- Performs a bandit task.
- I.e. Spaun has to guess a number between 0 and 3 that has the best reward.
- After each guess, it is given a 0 for no reward and a 1 for reward.
- Spaun learns this task and performs similarly to rats.
- `https://youtu.be/vuGDYajWyhU`

Serial Working Memory

- Spaun must memorize a list of numbers, then output the same list
- This task exhibits interesting encoding patterns
- For example, it performs well on short lists, but not on long lists
- This is similar to human performance
- `https://youtu.be/XxIzmkWygjY`

Counting

- Spaun is presented with a starting value and a count value, and it is to count up from that starting value.
- Spaun exhibits behavior known as Weber's Law in psychology.
- Essentially, Spaun is able to write the final value (which is the sum)
- `https://youtu.be/mP7DX6x9PX8`

Question Answering Task

- Spaun is presented with a list, then asked questions about the list.
- Question 1: What is at position x?
- Question 2: What position is x at?
- `https://youtu.be/pPPXncTBv4o`

Rapid Variable Creation

- Given example syntactic input/output patterns (e.g., 0 0 7 4 $\rightarrow$ 7 4; 0 0 2 4 $\rightarrow$ 2 4; etc.), Spaun should complete a novel pattern given only the input.
- In example: (e.g., 0 0 1 4 $\rightarrow$?)
- `https://youtu.be/tPRbphzQ-T8`

Fluid Reasoning

- Given 3 sets of numbers with an underlying pattern, Spaun must figure out the pattern.
- `https://www.youtube.com/watch?v=qcZe-2eWaeM`

References

1. Eliasmith, C., Stewart T. C., Choo X., Bekolay T., DeWolf T., Tang Y., Rasmussen, D. (2012). *A large-scale model of the functioning brain.* Science. Vol. 338 no. 6111 pp. 1202-1205. DOI: 10.1126/science.1225266.

2. [NEF book] Eliasmith, C., Anderson, C.H. (2003). Neural engineering: Computation, representation, and dynamics in neurobiological systems. Cambridge, MA: MIT Press.

3. `http://nengo.ca/`

4. `https://github.com/nengo`