Spaun: A biologically realistic large-scale functional brain model

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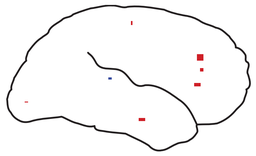
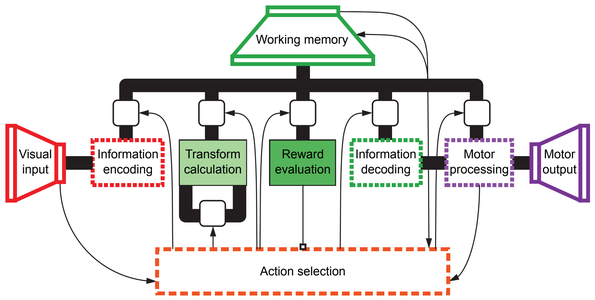
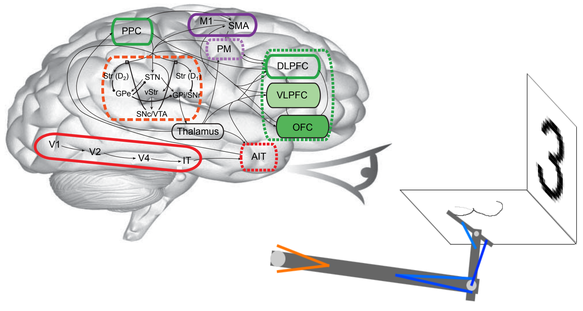
The Semantic Pointer Architecture Unified Network (Spaun) is a network of **2.5 million interconnected artificial spiking neurons**.



Spaun is composed of groups of neurons that perform functions necessary to complete cognitive tasks. It **flexibly coordinates** those groups depending on the cognitive task being performed.



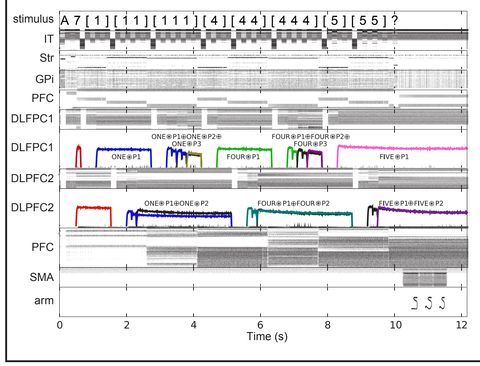
These functionally related groups of neurons are mapped onto brain areas consistent with our current understanding of functional neuroanatomy. Spaun can be manipulated in order to **test hypotheses in neuroscience**.



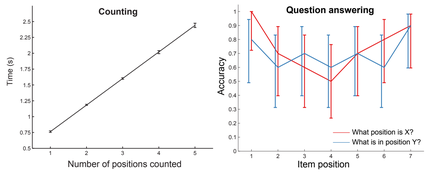
Theory

1m	CNS	
10cm	Systems	⇐ Nengo modelling software[1]
1cm	Maps	⇐ Semantic pointer architecture[2] $List = Pos1 \circledast Item1 \oplus Pos2 \circledast Item2 \ldots$
1mm	Networks	⇐ Neural Engineering Framework $\omega_{ij} = \alpha_j \mathbf{d}_i \mathbf{e}_j \qquad \hat{\mathbf{x}} = \sum a_i(\mathbf{x}) \mathbf{d}_i$
100µm	Neurons	⇐ Single-cell modelling $\frac{dV}{dt} = -\frac{1}{RC}(V(t) - J(t)R)$
1µm	Synapses	⇐ Post-synaptic current curves $h(t) = e^{-t/\tau}$ if $t > 0$
10nm	Molecules	

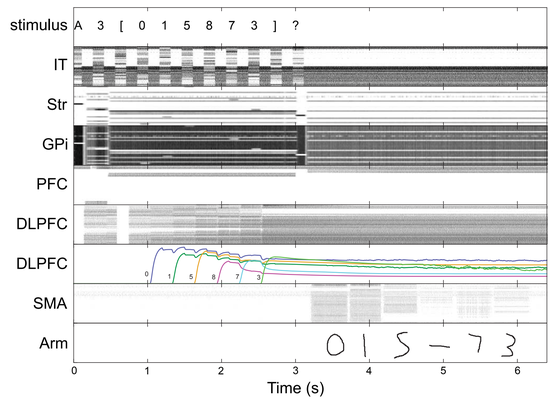
Spaun performs tasks like humans

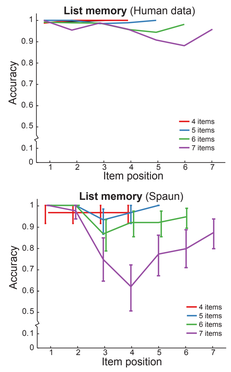


	Chance	Humans	Spaun
Image recognition	10%	98%	94%
Fluid reasoning	13%	89%	88%

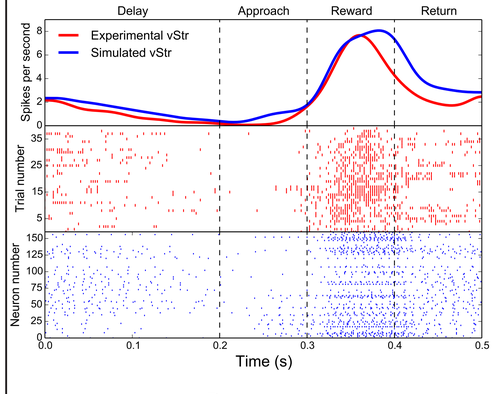


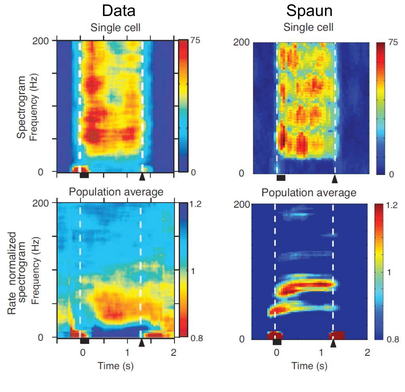
Spaun makes mistakes like humans

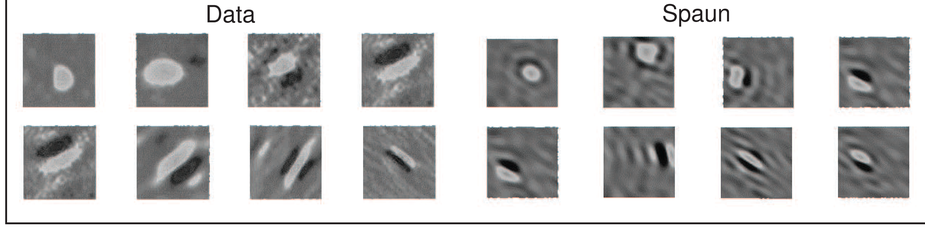




Spaun matches experimental data





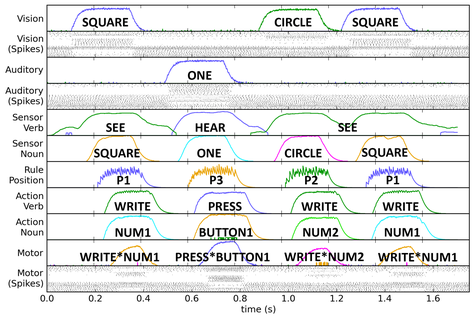


Spaun can perform 8 cognitive tasks using **only visual information** and **without external intervention**.

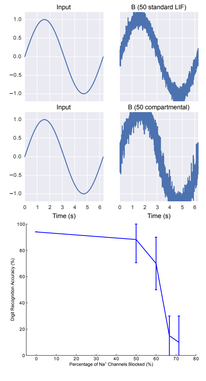
Copy drawing "Copy this 2."	A 0 [2] ? ⇒ 2
Image recognition "Write a 2."	A 1 [2] ? ⇒ 2
Gambling "Try slot machine 0, 1 or 2."	A 2 ? ⇒ 0 ⇒ 0 A 2 ? ⇒ 1 ⇒ 1 A 2 ? ⇒ 1 ⇒ 1
List memory "Write the list 0 1 5 8 7 3."	A 3 [0 1 5 8 7 3] ? ⇒ 0 1 5 8 7 3
Counting "Starting from 3, count 5."	A 4 [3] [5] ? ⇒ 8
Question answering "Write the 2nd number in 0 1 5 8 7 3."	A 5 [0 1 5 8 7 3] [P] [2] ? ⇒ 1
Rapid variable creation "Complete the pattern: 0014→14, 0094→94, 0074→?"	A 6 [0 0 1 4] [1 4] [0 0 9 4] [9 4] [0 0 7 4] ? ⇒ 74
Fluid reasoning "Fill in the last cell."	A 7 [1] [1 1] [1 1 1] [4] [4 4] [4 4 4] [5] [5 5] ? ⇒ 555

Recent developments

General instruction processing



Conductance neuron model[3]



A large-scale model of the functioning brain. *Science*, 338:1202–1205.
Chris Eliasmith, Terrence C. Stewart, Xuan Choo, Trevor Bekolay, Travis DeWolf, Yichuan Tang, and Daniel Rasmussen (2012).

1) Trevor Bekolay et al. (2013). Nengo: a Python tool for building large-scale functional brain models. *Frontiers in Neuroinformatics* 7.
Available at `http://github.com/nengo/nengo`

2) Chris Eliasmith (2013). *How to build a brain: A neural architecture for biological cognition*. Oxford University Press.

3) Armin Bahl, Martin B. Stemmler, Andreas V.M. and Arnd Roth (2012). Automated optimization of a reduced layer 5 pyramidal cell model based on experimental data. *Journal of Neuroscience Methods*, 210:22–34.

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