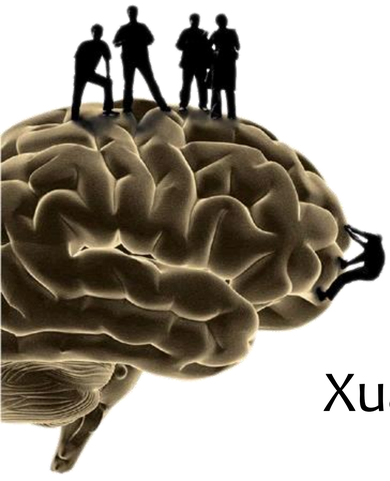


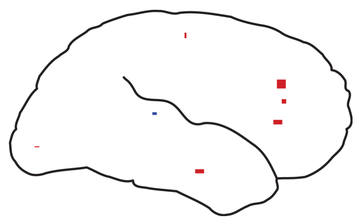
Spaun: A Biologically Inspired, Large-Scale Functional Brain Model

Xuan Choo , Trevor Bekolay, Terrence C. Stewart, Travis DeWolf, Yichuan Tang, Daniel Rasmussen, Jan Gosmann, Chris Eliasmith

UNIVERSITY OF WATERLOO

CNRG computational neuroscience research group
compneuro.uwaterloo.ca

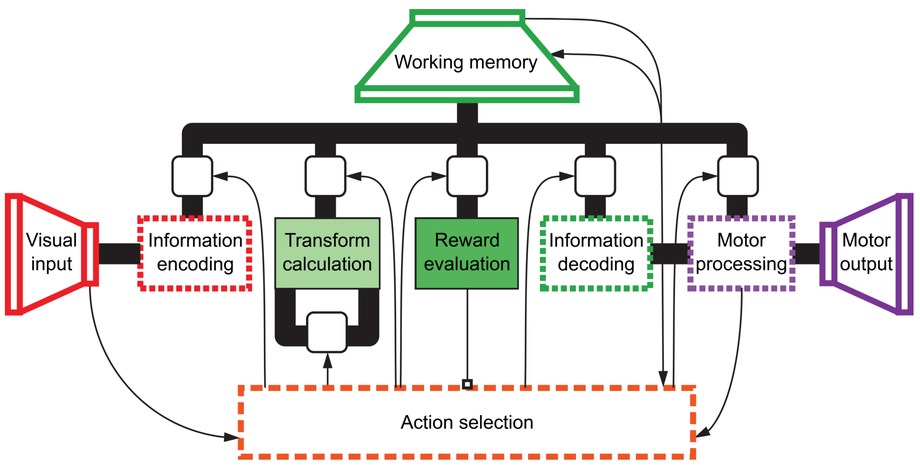
The Semantic Pointer Architecture Unified Network (Spaun) is a network of about **2.5 million interconnected artificial spiking neurons**.



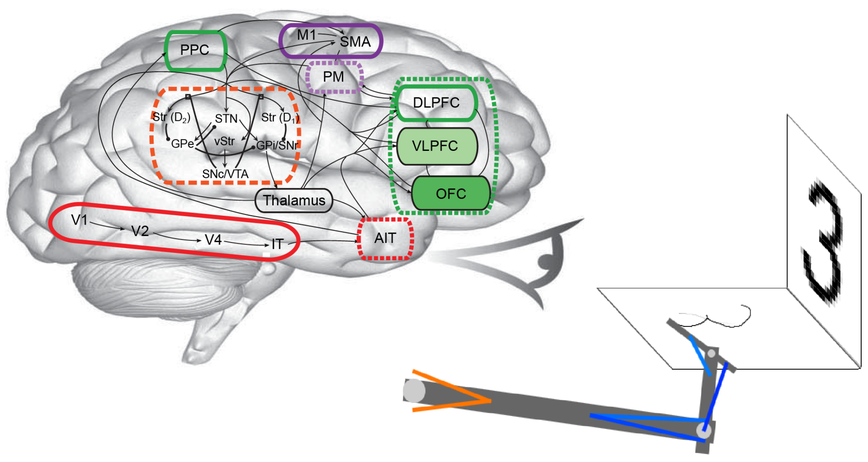
Spaun can perform 8 different cognitive tasks using **only visual information and without external intervention**:

- Copy drawing
- Digit classification
- Gambling
- List memory
- Counting
- Question answering
- Rapid variable creation
- Fluid reasoning

Spaun is composed of groups of anatomically and physiologically matched 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 brain function. Spaun can be manipulated in order to **test hypotheses in neuroscience**.



Theory

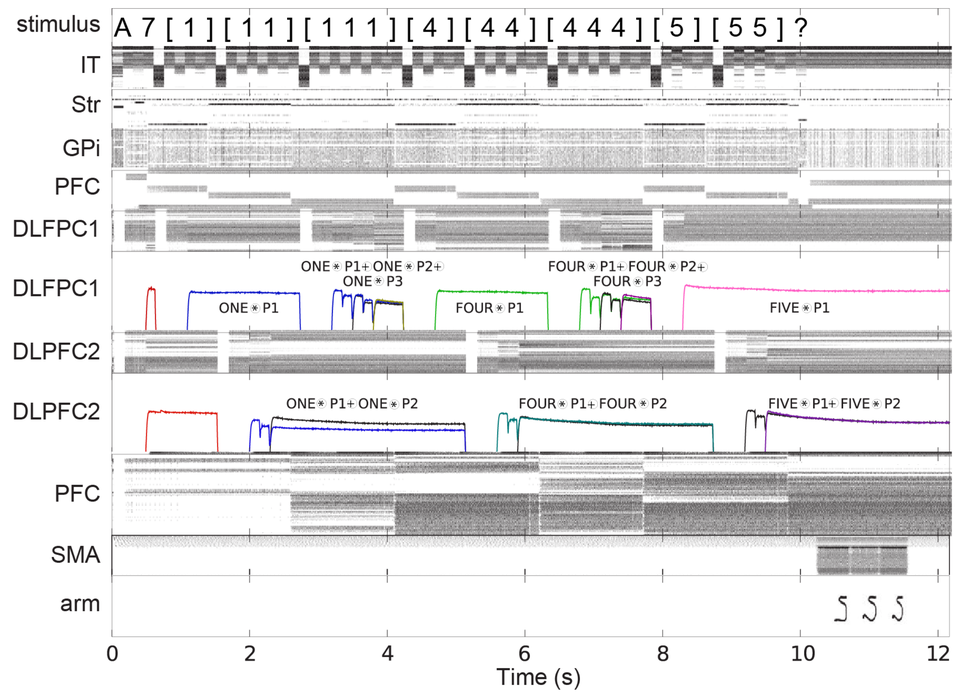
1m	CNS	← Nengo modelling software
10cm	Systems	← Semantic pointer architecture
		$List = Pos1 \circledast Item1 + Pos2 \circledast Item2 \ldots$
1cm	Maps	
1mm	Networks	← Neural Engineering Framework
		$\omega_{ij} = \alpha_j \mathbf{d}_i \mathbf{e}_j$
		$\hat{\mathbf{x}} = \sum_i a_i(\mathbf{x}) \mathbf{d}_i$
100μm	Neurons	
1μm	Synapses	
		$a_i(x) = G_i[\alpha_i \mathbf{e}_i \cdot \mathbf{x} + J_i^{bias}]$
		$\frac{dV}{dt} = -\frac{1}{RC}(V(t) - J(t)R)$
10nm	Molecules	

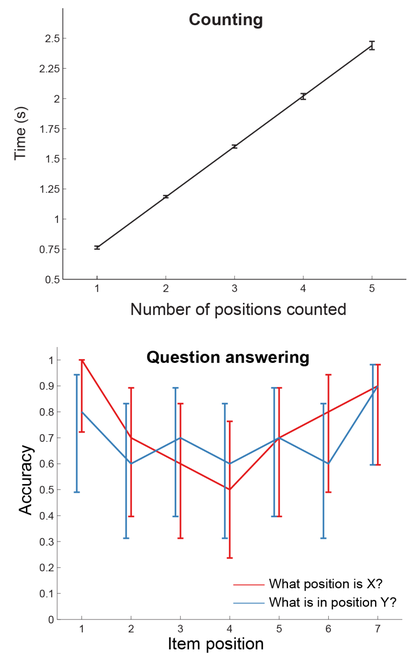
Chris Eliasmith, Terrence C. Stewart, Xuan Choo, Trevor Bekolay, Travis DeWolf, Yichuan Tang, and Daniel Rasmussen (2012). A large-scale model of the functioning brain. *Science*, 338: 1202-1205

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

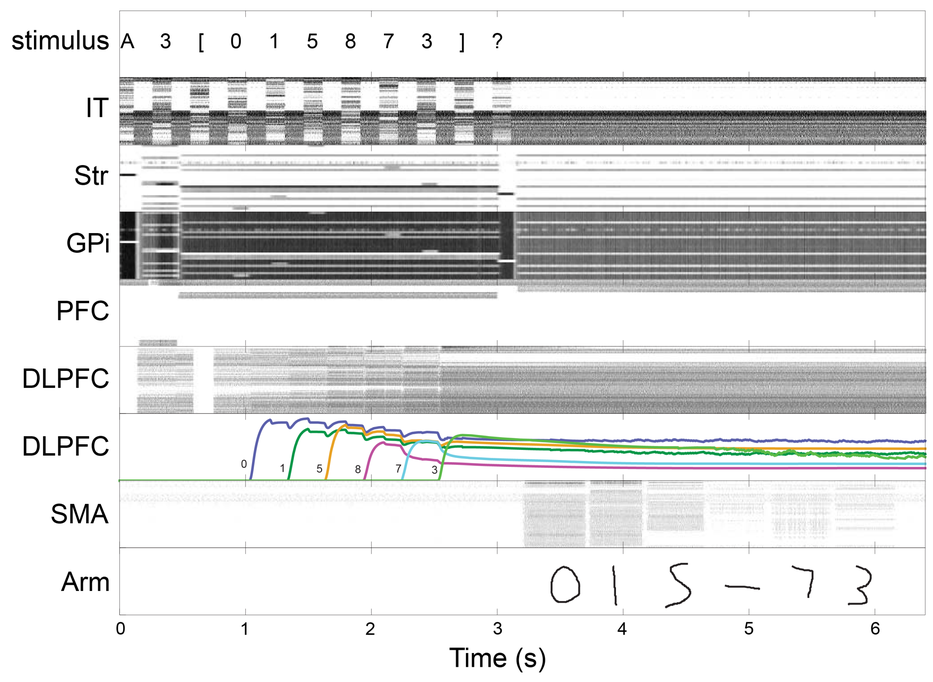
Armin Bahl, Martin B. Stemmler, Andreas V.M. Herz, and Arnd Roth (2012). Automated optimization of a reduced layer 5 pyramidal cell model based on experimental data. *Journal of Neuroscience Methods*, 210: 22-34

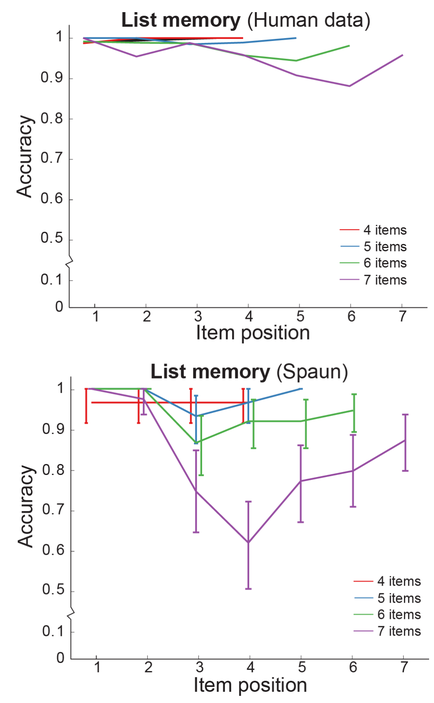
Spaun performs tasks like humans



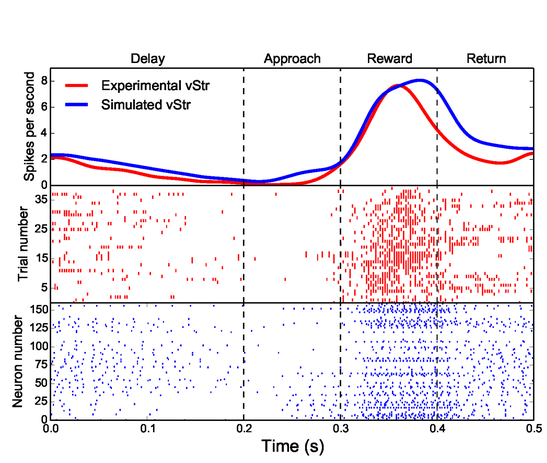


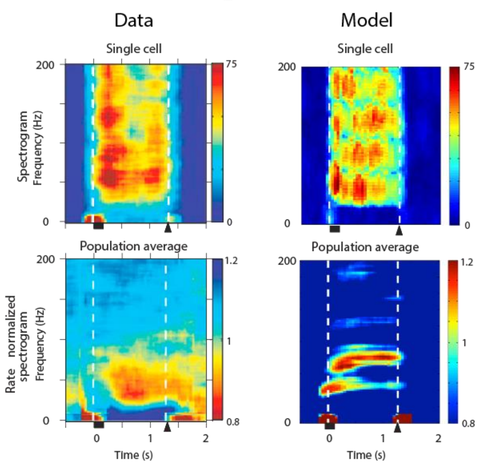
Spaun makes mistakes like humans

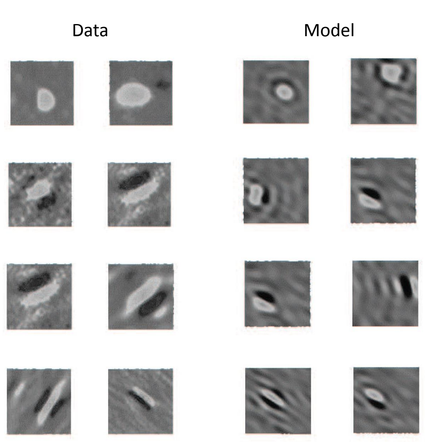




Spaun matches experimental data

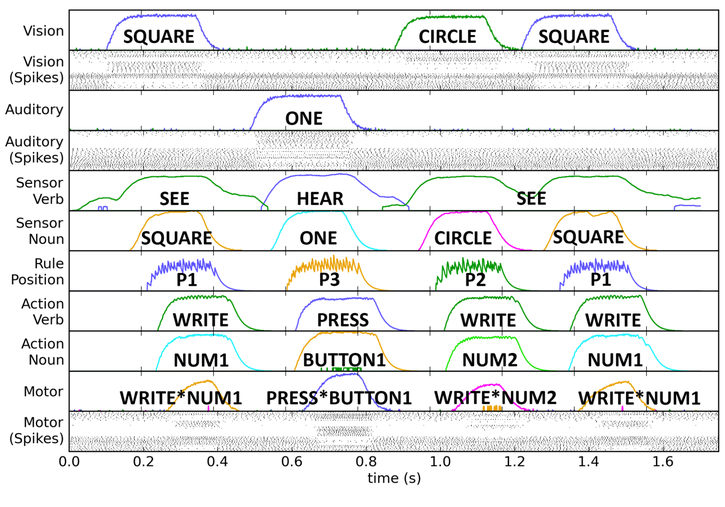






Spaun+ : More neural detail and cognitive performance

General instruction processing



Conductance neuron model (Bahl et. al. 2012)