

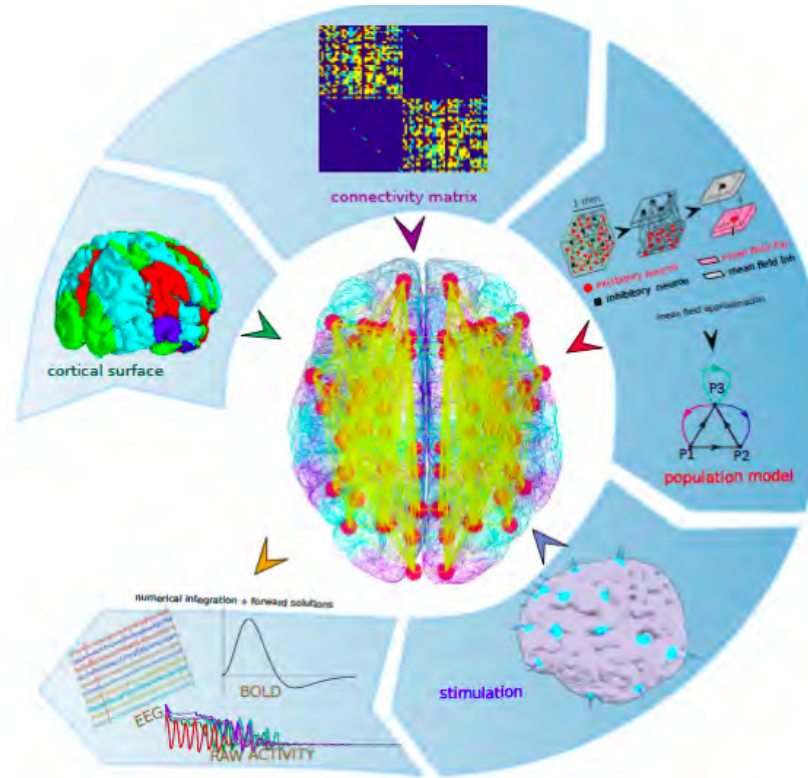
# **Large-scale neural models**

Review of three competing models  
Antonio Ulloa, PhD

# Large-scale neural models

1. The Virtual Brain
2. Spaun (Semantic Pointer Architecture  
Unified Network)
3. HMAX

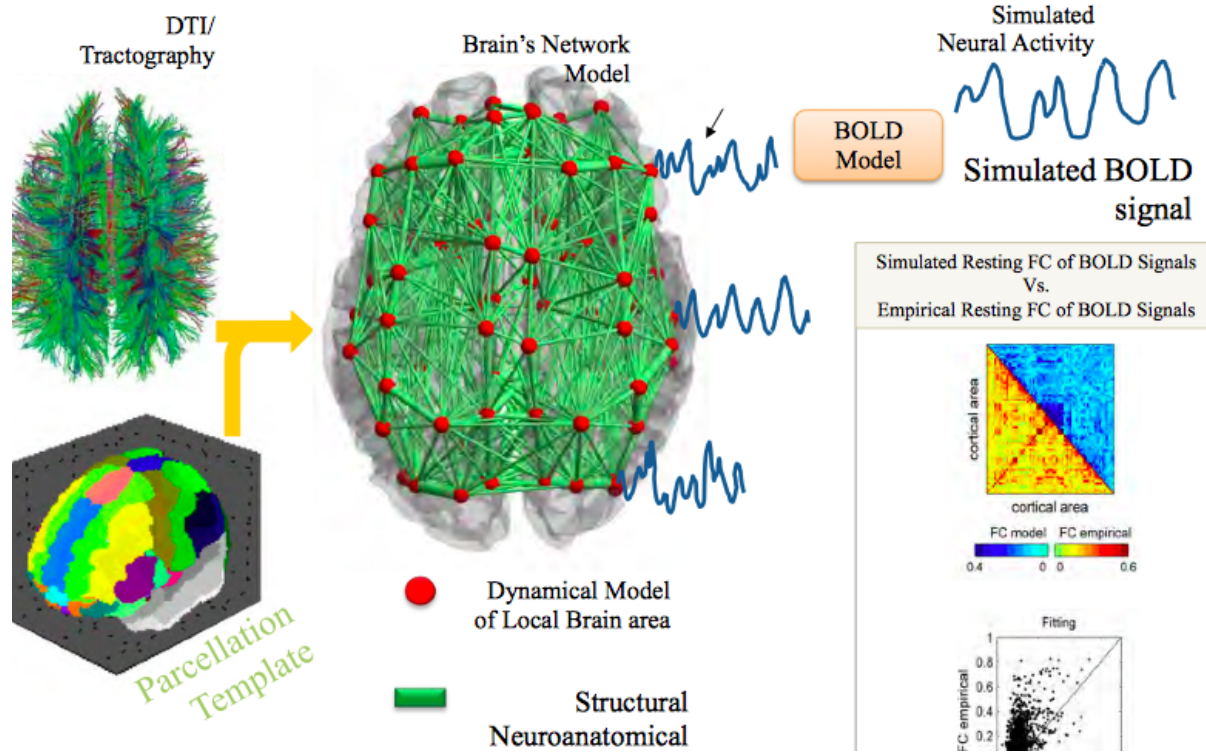
# The Virtual Brain



# **The Virtual Brain: Architecture**

Two types of coupling: global (connectome, white matter tracts, time delay) and local (neighborhood, grey matter, no time delay).

# The Virtual Brain: Architecture



# The Virtual Brain: Basic Unit

Local field potential and synaptic activity:

- Stefanescu-Jirsa 3d
- Stefanescu-Jirsa 2d
- Wong-Wang

Firing rate:

- Wilson-Cowan
- Brunel-Wang
- Jansen-Rit

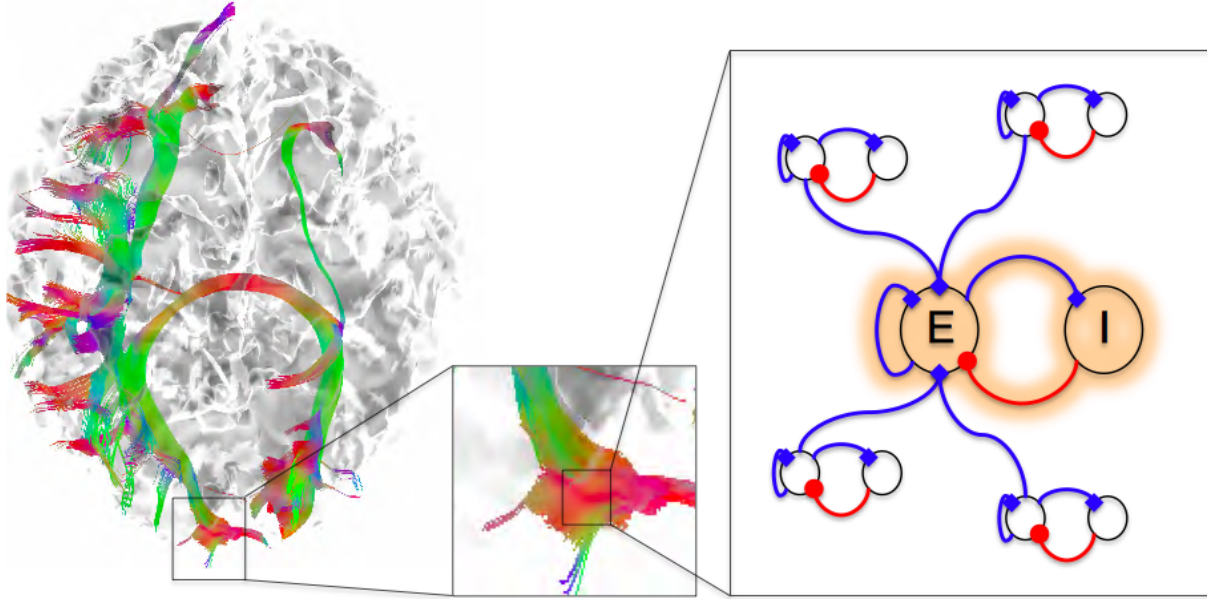
# The Virtual Brain: Basic Unit

Population activity

Short range input

Long range input

$$\dot{\Psi}(x, t) = N(\Psi(x, t)) + \int_{\Gamma} g_{local}(x, x') S(\Psi(x', t)) dx' + \int_{\Gamma} g_{global} S(\Psi(x', t - \frac{|x-x'|}{v})) dx' + I(x, t) + \xi(x, t)$$



# **The Virtual Brain: Task**

Resting state



# **The Virtual Brain: Summary**

The Virtual Brain is not a model per se, but a neuroinformatics package that allows you to put together anatomical and structural data and underlying neural population model in order to test theories of brain function and (in the future) aid in brain surgery decision making.

# Spaun

Model of the brain with the following functions: working memory, action selection by the BG, motor and visual perception. It simulates 2.5 millions neurons.

# Spaun: Basic Unit

The Spaun model is defined by the following objects:

1. **Ensembles**

Groups of neurons that encode time-varying vectors using leaky integrate-and-fire neurons

2. **Nodes**

Sensory inputs and motor outputs

3. **Connections**

Description of how nodes and ensembles are connected (connection weight matrix)

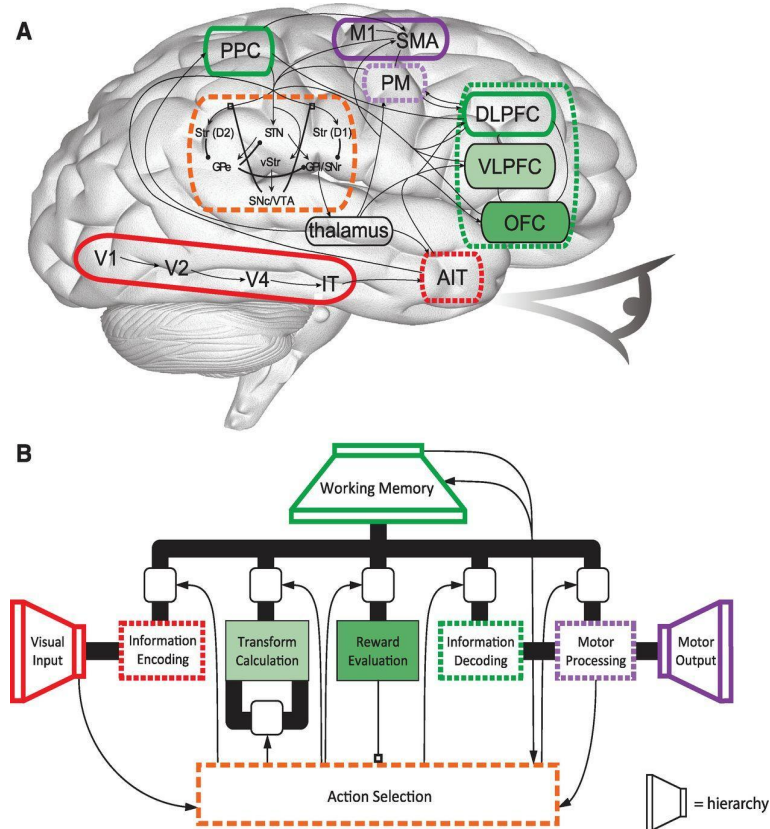
4. **Probe**

Definition of which simulation data is going to be collected

5. **Network**

Encapsulation of a functionally related group of interconnected nodes and ensembles

# Spaun: Architecture



C Eliasmith et al. Science 2012;338:1202-1205

# Spaun: Task

The Spaun model performs 8 different tasks:

Copy drawing

Image recognition

Reinforcement learning

**Serial working memory**

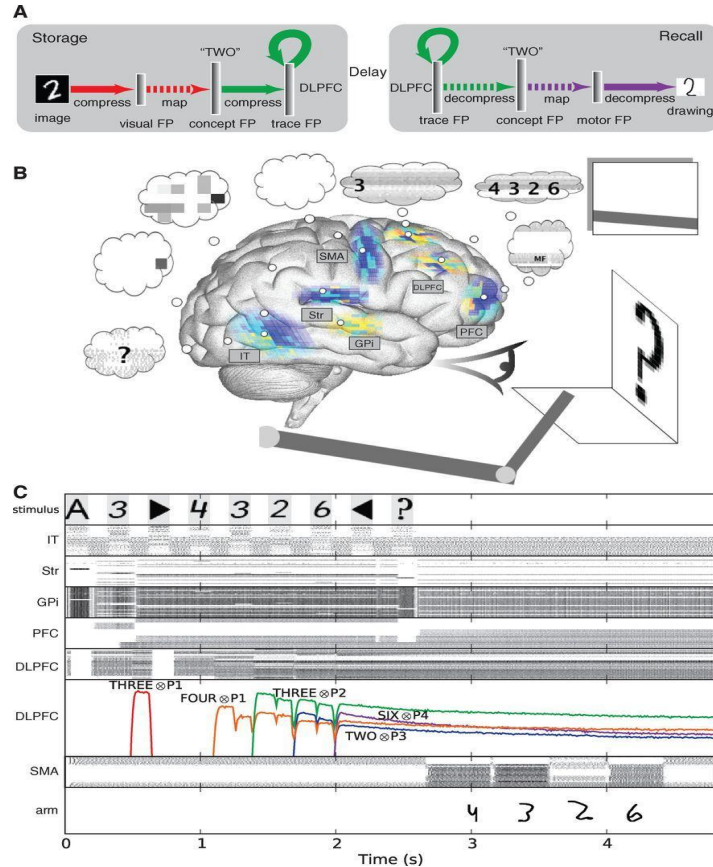
Counting

Question answering

Rapid variable creation

Fluid reasoning

# Spaun: task

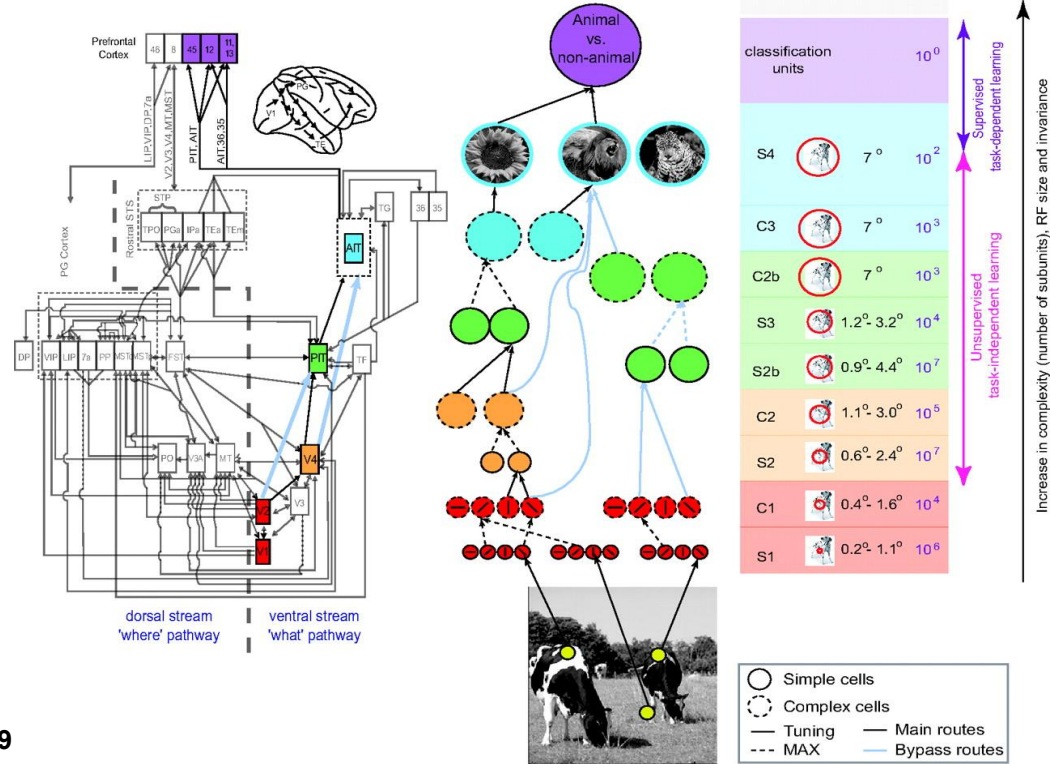


C Eliasmith et al. Science 2012;338:1202-1205

# HMAX

Model of the ventral pathway of the visual system. It simulates 10 million neurons arranged in a hierarchical structure where, as you go up in the hierarchy, there is an increase in the invariance to position and scale, as well as an increase in the size of the receptive fields.

# HMAX: Architecture



**Serre T et al. PNAS 2007;104:6424-6429**



# HMAX: Basic Unit

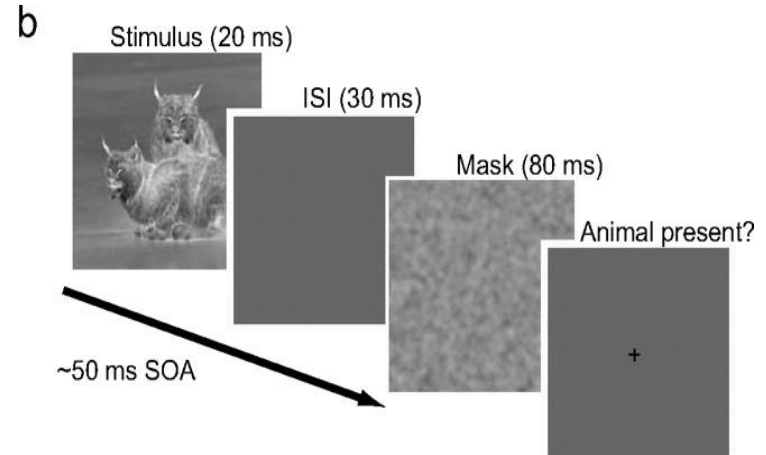
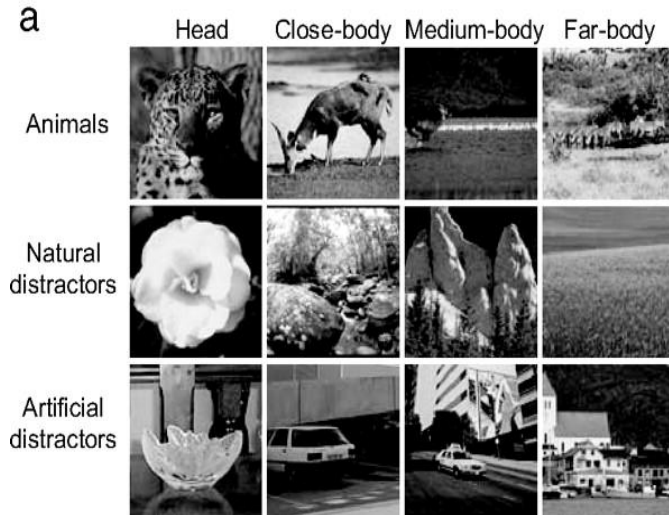
- S units perform a bell-shaped tuning operation over their inputs. The response  $y$  of a simple unit receiving the pattern of synaptic inputs  $(x_1 \dots, x_n)$  from the previous layer is given by:

$$y = \exp - \frac{1}{2\sigma^2} \sum_{j=1}^{n_{s_k}} (w_j - x_j)^2$$

- C units perform a *max* operation. The response  $y$  of a complex unit corresponds to the response of the strongest of its afferents  $(x_1 \dots, x_n)$  from the previous S layer:

$$y = \max_{j=1 \dots n_{C_k}} x_j.$$

# HMAX: Task



Serre T et al. PNAS 2007;104:6424-6429

# Model comparison

Model	What it models	Basic Unit	Task	It simulates
TVB	Unlimited number of brain regions, as well as structural white matter tracts	Six different population models to choose from	Resting state (no behavioral task), TMS, visual, auditory stimulation	Electrophysiological, EEG, MEG, fMRI, lesions, seizures
Spaun	V1, V2, V4, IT, PPC, M1, SMA, PM, DLPFC, VLPFC, OFC, TH, BG, AIT	Leaky integrate and fire neurons	Copy drawing, image recognition, reinforcement learning, serial working memory, counting, question answering, rapid variable creation, fluid reasoning	Electrophysiological, visual recognition, arm movement
HMAX	V1, V2 , V4, IT, PFC	S (bell-shaped tuning) and C (max operation)	Animal vs non-animal categorization	Electrophysiological
LSNM	V1/V2, V4 (Ai, Aii), IT (ST), and PFC	Wilson-Cowan population units	Visual (auditory) DMS task	Electrophysiological, PET, fMRI, MEG