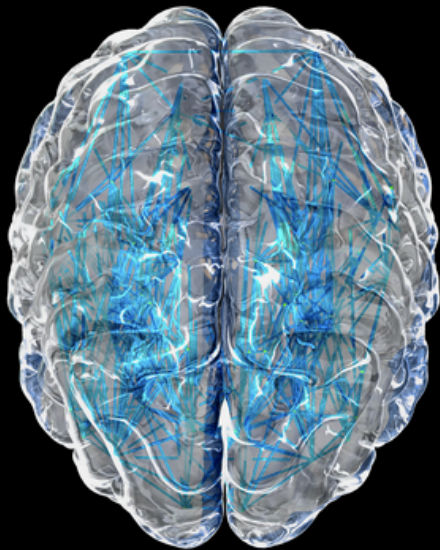


# A Tutorial in Connectome Analysis (0): Topological and Spatial Features of Brain Networks



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United Kingdom

<http://www.dynamic-connectome.org>

<http://neuroinformatics.ncl.ac.uk/>



[@ConnectomeLab](https://twitter.com/ConnectomeLab)

# Schedule

**9:30 (0) Overview**

**(I) Introduction to Graph Theory and Neural networks**

***Practical***

***11:00 30 minute coffee break***

**11:30 (II) Spatial properties of neural networks**

***Practical***

**(III) Topological properties of neural networks**

MANGA ENTERTAINMENT PRESENTS A MAMORU OSHII FILM GHOST IN THE SHELL BASED ON THE ORIGINAL MANGA BY MASAMUNE SHIROW

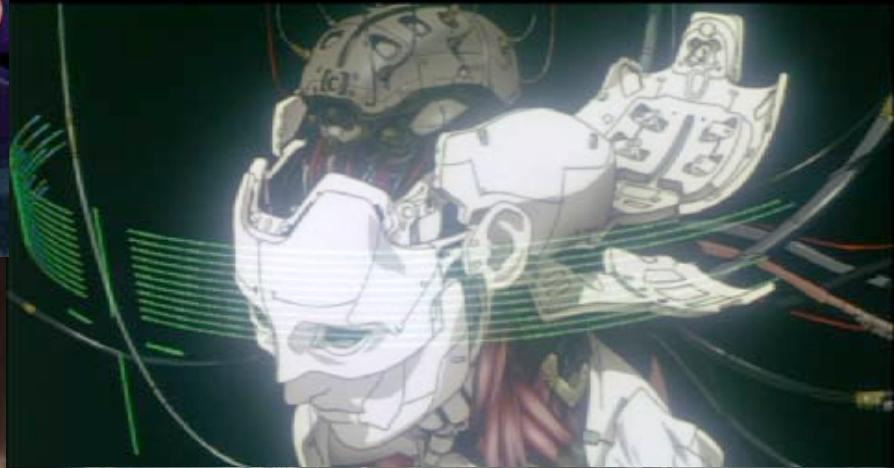
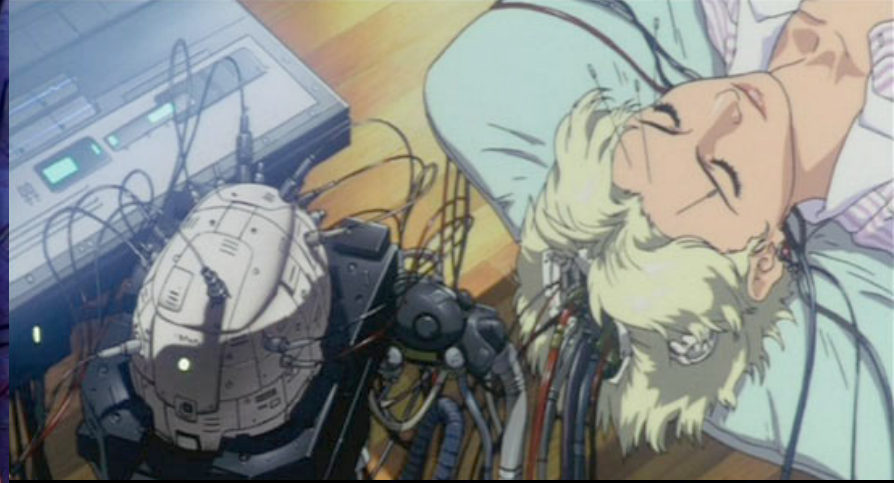
AT A CINEMA NEAR YOU FROM DECEMBER 8TH

# GHOST IN THE SHELL

IT'S FOUND ITS VOICE... NOW IT NEEDS A BODY

FEATURING  
"ONE MAN'S WARFARE"  
BY PASSENGERS  
(BRILLIAN EMO + 12)

SCREENPLAY BY MAMORU OSHII DIRECTOR OF ANIMATION BY KAZUSHIGE ITO DIRECTOR OF FILM BY TOSIYUKI KUSAKABE PRODUCED BY HIROMASA OGURA EXECUTIVE PRODUCERS KENJI KANAI GORO OHTA KAZUYUKI WAKABAYASHI PRODUCED BY YOSIYUKI OHURA  
MANGA BY SHOUJI KANAMORI ARTS BY TATSUYUKI TANOYUKI EDITOR MITSUO EDO MUSIC BY TARASHI WATABE EXECUTIVE PRODUCERS SHUICHI TAKESHI DIRECTOR OF PHOTOGRAPHY HISAO SHIRAI  
PRODUCED BY KODANSHA ANIMATED BY BANDAI VISUAL IN ASSOCIATION WITH MANGA ENTERTAINMENT  
PRODUCTION BY PRODUCTION I.G. PRODUCED BY YOSHIMASA NIZO DIRECTOR OF PHOTOGRAPHY KEN IYADOME EDITOR MITSUO EDO EXECUTIVE PRODUCERS TETSURO HAYASHIYA SHIGERU WATANABE ARDY FRANK  
RELEASED BY MANGA ENTERTAINMENT LTD. 100% JAPANESE ANIMATION. MANGA ENTERTAINMENT LTD. TOKYO, JAPAN. © 2005 MANGA ENTERTAINMENT LTD.



*You will not find a corpse...*

# The Computer and the Brain

Because of low speed and accuracy of calculations  
*“large and efficient natural automata are likely to be highly parallel”* and have *“low logical depth”*  
(number of processing steps)

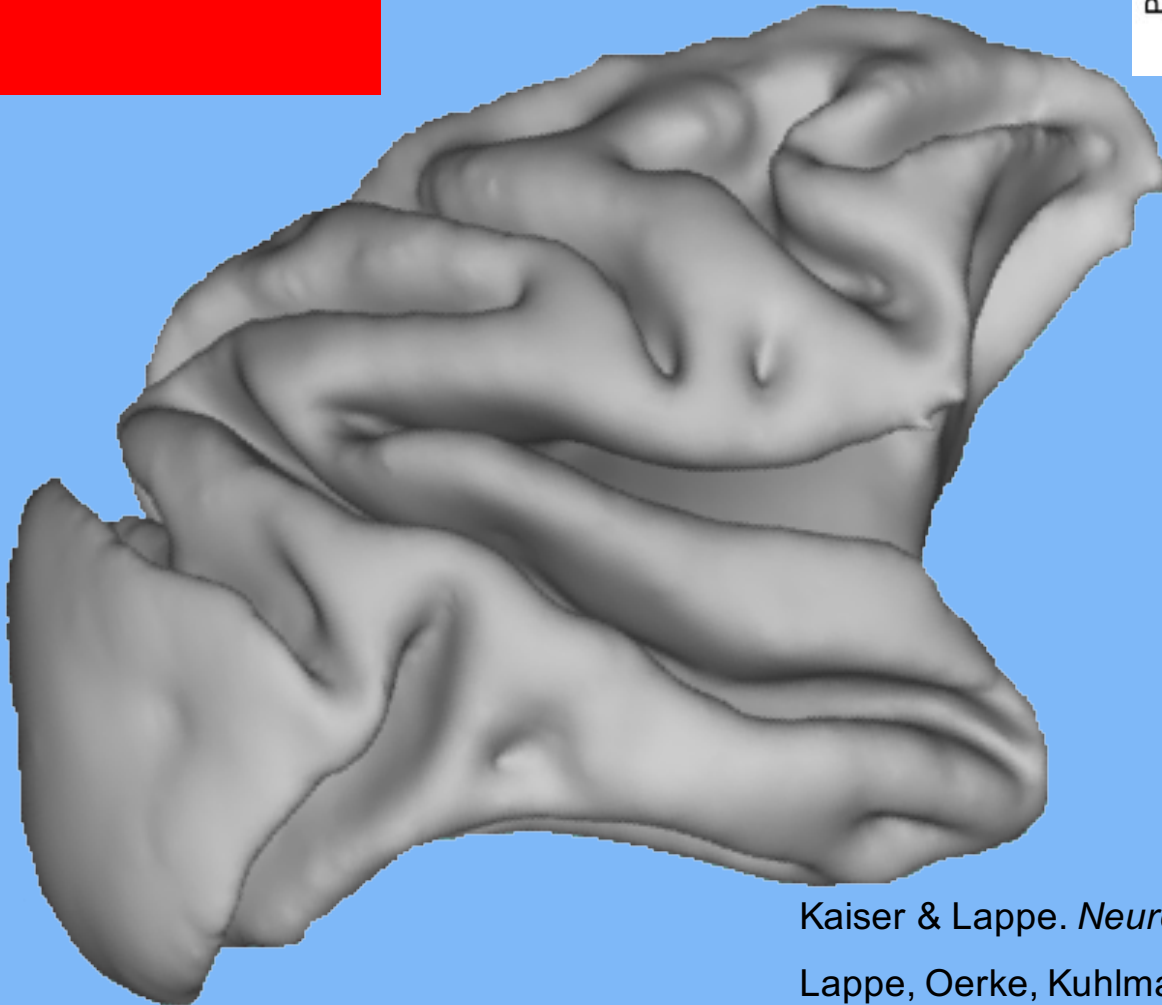
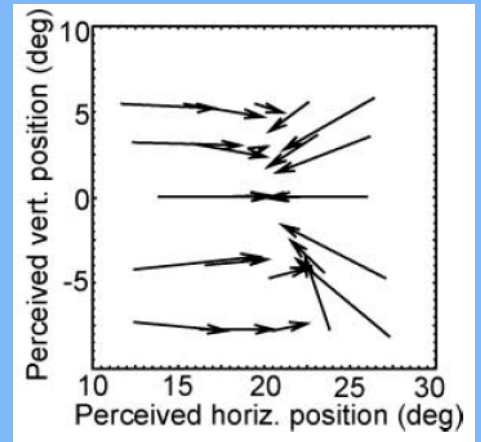
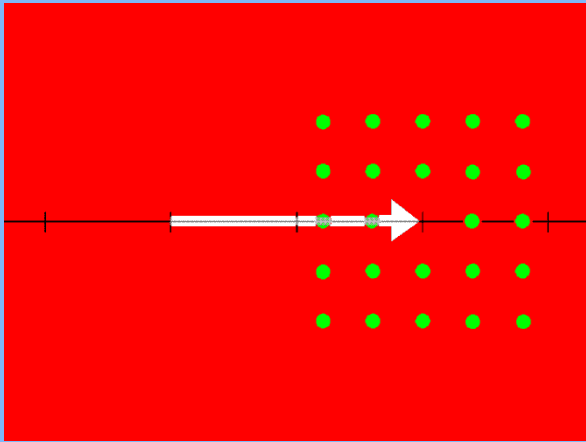


**John von Neumann**

The Computer and the Brain (Yale University Press, 1958)

## **Update after 50 years:**

Kaiser (2007) Brain Architecture: A Design for Natural Computation.  
*Philosophical Transactions of the Royal Society A*, 365:3033-3045



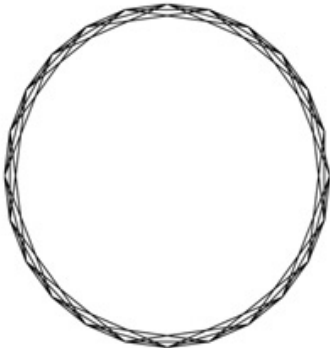
Kaiser & Lappe. *Neuron*, 2004

Lappe, Oerke, Kuhlmann, Kaiser, *J. Vision*, 2006

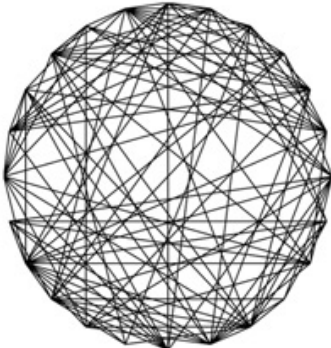
# Function influences network structure

*Or Form Follows Function during brain evolution*

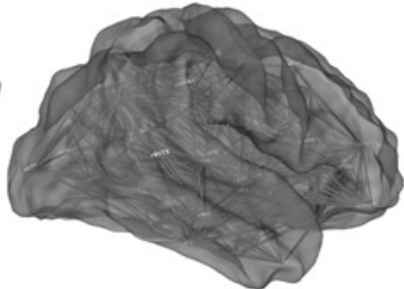
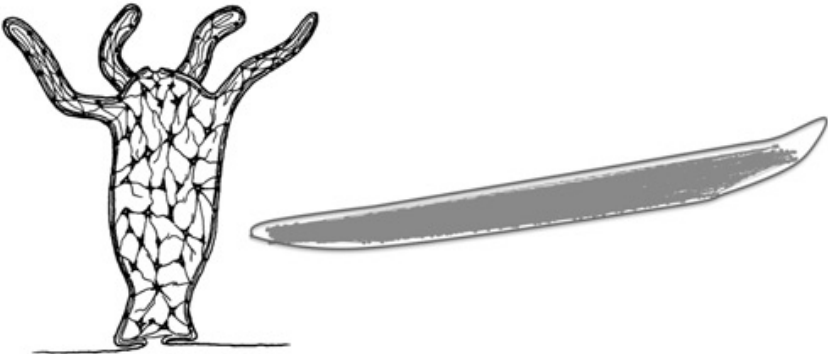
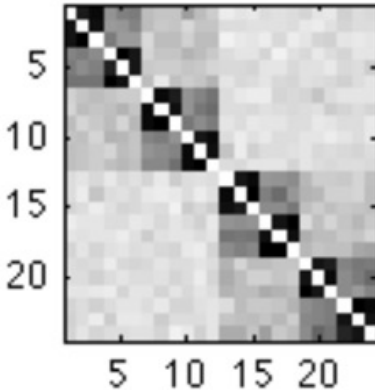
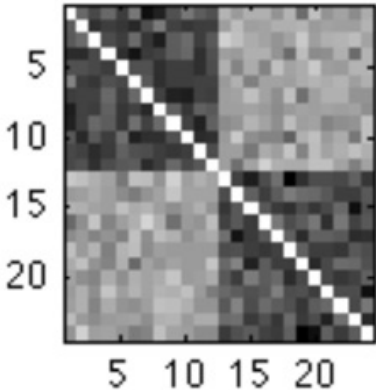
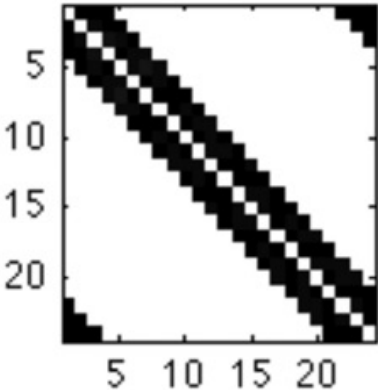
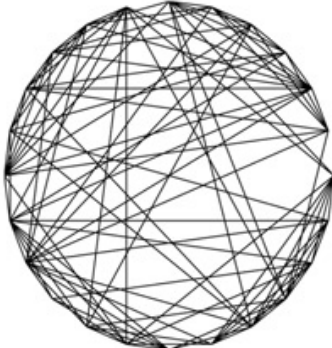
(A) Regular



(B) Modular



(C) Hierarchical



Kaiser & Varier (2011)  
*Network: Computation  
in Neural Systems*  
22(1-4): 143-147

# The Mind of a Fly

*Brain connectivity in Drosophila melanogaster*

A



*Drosophila melanogaster*



*Mus musculus*



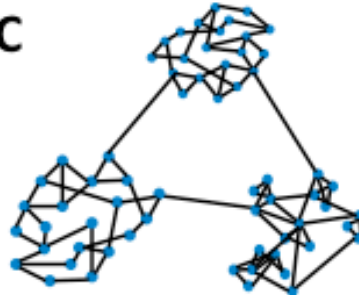
*Macaca mulatta*



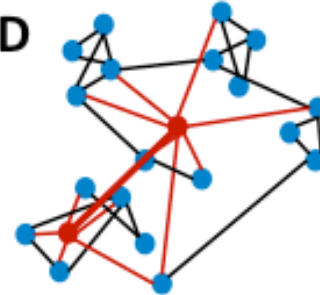
B



C



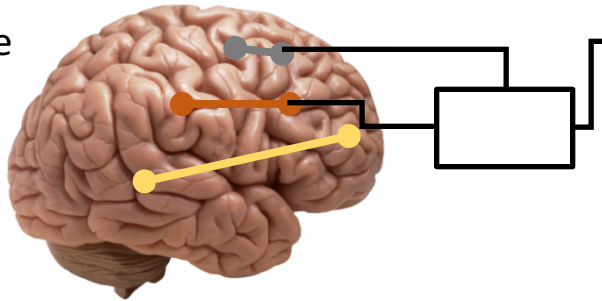
D



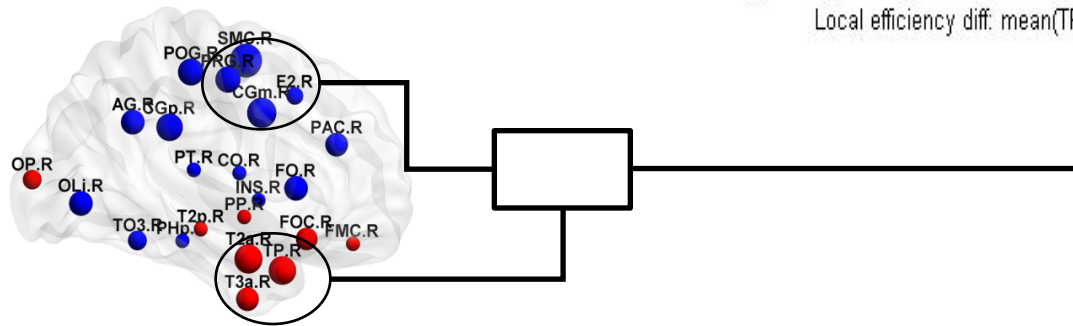
# ... and predicts subtypes of dementia

Correlation with clinical measures  
and **group** differentiation

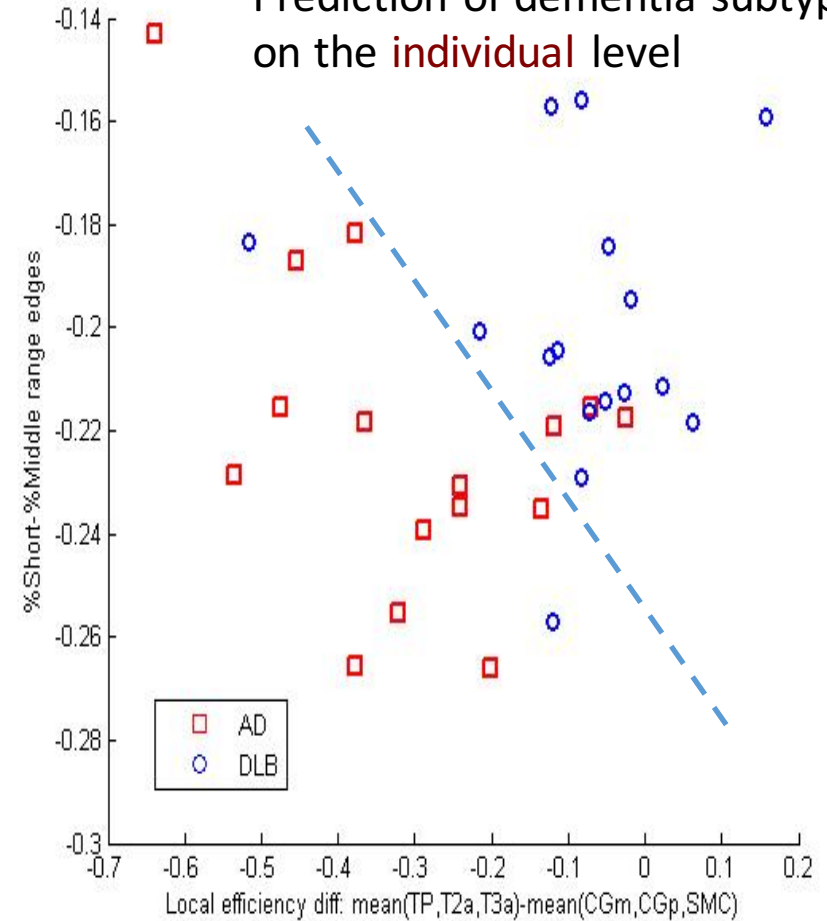
Short-Middle range  
connections



Local Efficiency



Prediction of dementia subtype  
on the **individual** level



81% Sensitivity  
87% Specificity  
0.88 AUC

*In preparation*

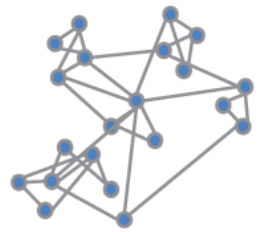


# Connectome topology not always sufficient as biomarker

Brains are non-linear systems: small system changes can have large effects on system behaviour

Connectome

Consequence Classification



Seizure

Epilepsy



Hallucinations

Schizophrenia



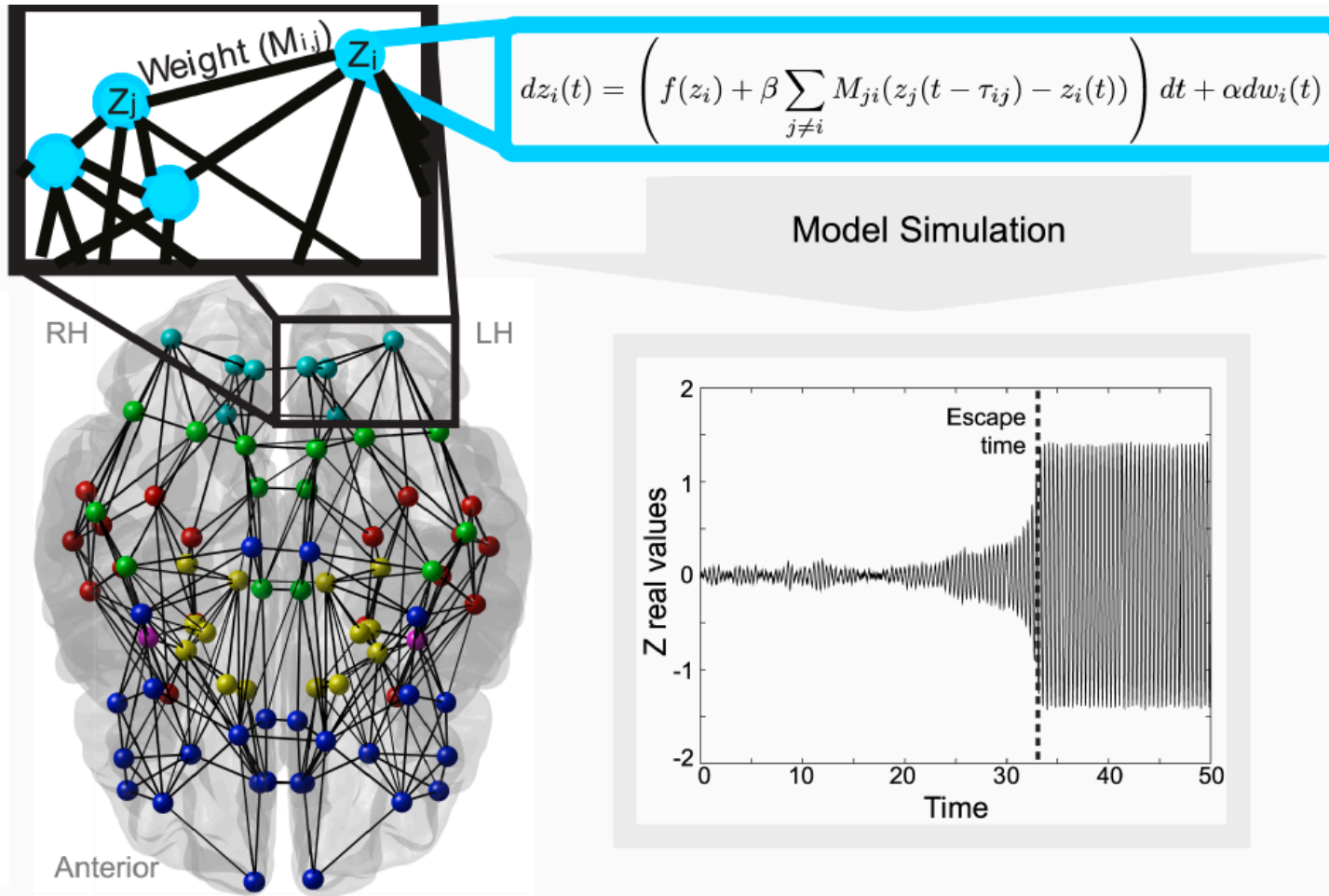
Seizure

Epilepsy

→ need for simulations of brain dynamics

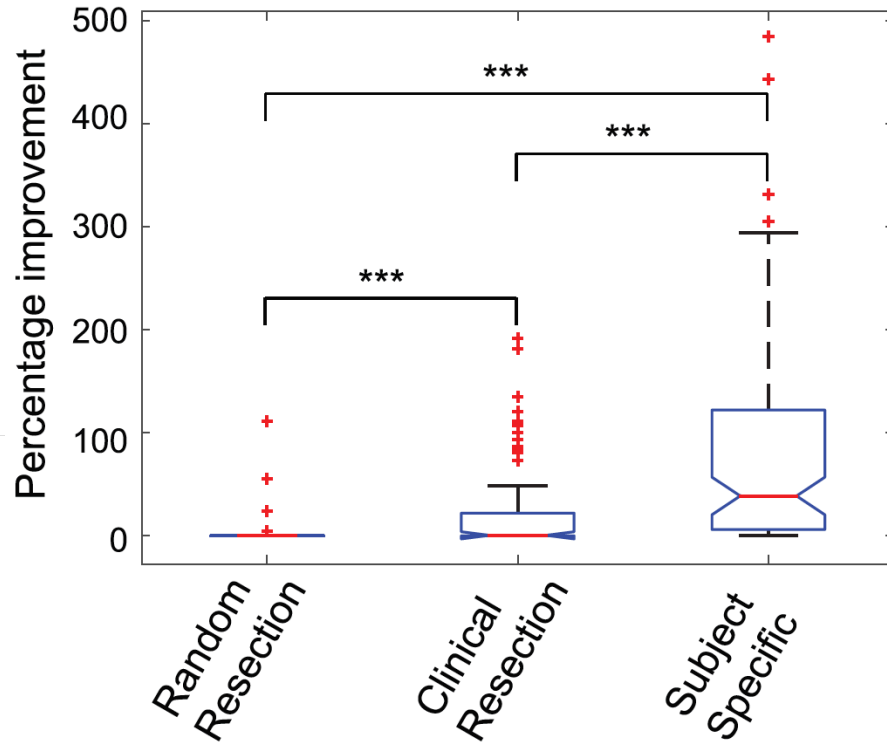
Kaiser, Frontiers in Human Neuroscience, 2013

# Computer simulations – predicting the location of epileptic tissue



Hutchings et al. *PLOS Computational Biology*, 2015

# Computer simulations – predicting the location of epileptic tissue



Percentage improvement (increase in escape time) for an individual patient

Effect of removing three brain regions

\*\*\* significance level  $p < 0.001$

## Percentage of patients with significant ( $p < 0.05$ ) improvements

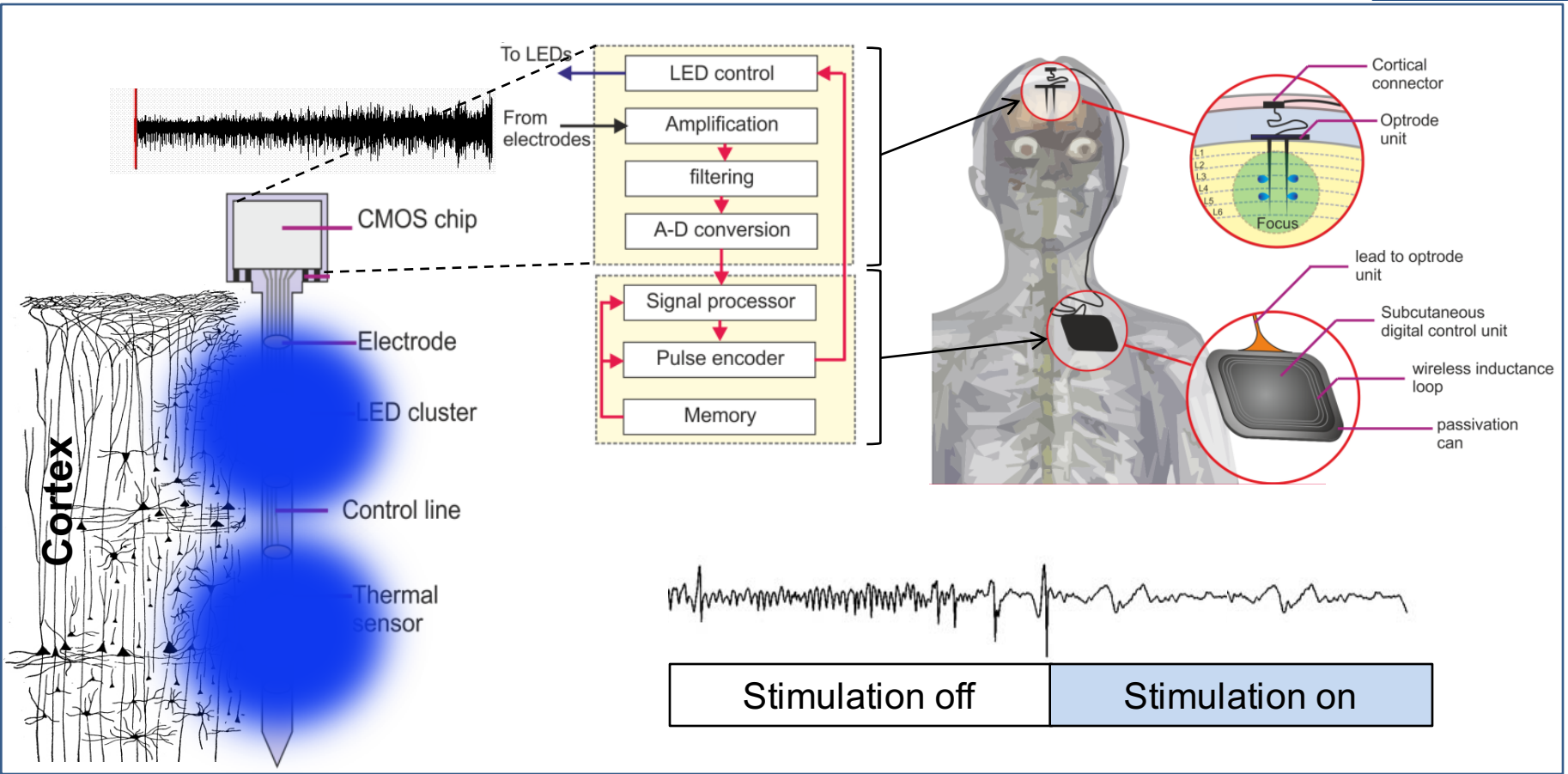
| Source                         | Clinical (%) | Patient Specific (%) |
|--------------------------------|--------------|----------------------|
| Model simulations              | 72.7         | 100                  |
| Spencer <i>et al.</i> 2008 [5] | 53–84        | -                    |
| Hemb <i>et al.</i> 2013 [6]    | 62–65        | -                    |
| de Tisi <i>et al.</i> 2011 [7] | 52–47        | -                    |
| Arruda <i>et al.</i> 1996 [43] | 50–93.6      | -                    |

# Computer simulations – predicting the effect of optogenetic stimulation

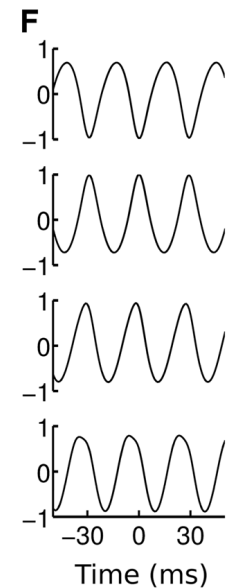
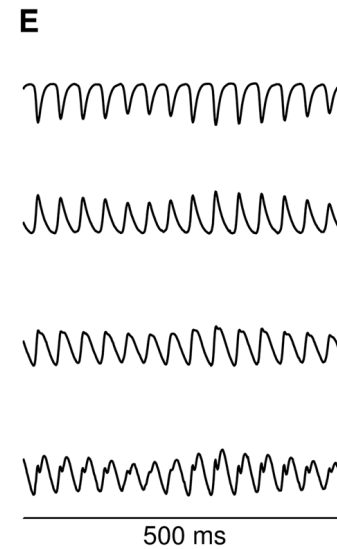
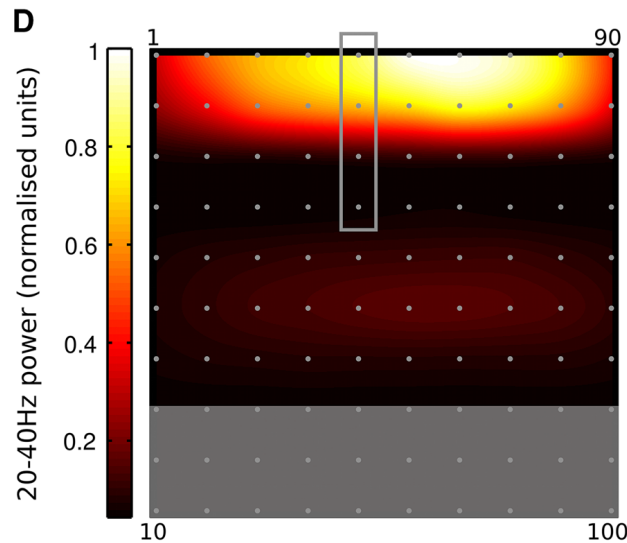
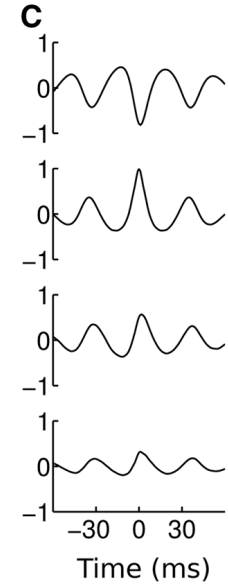
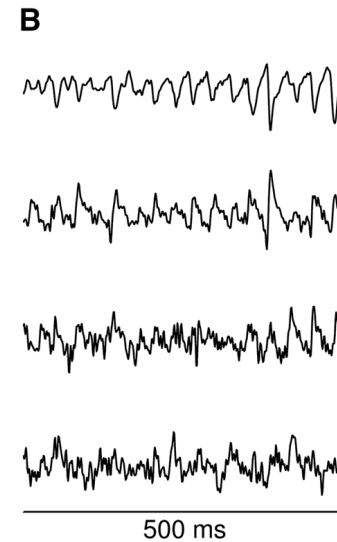
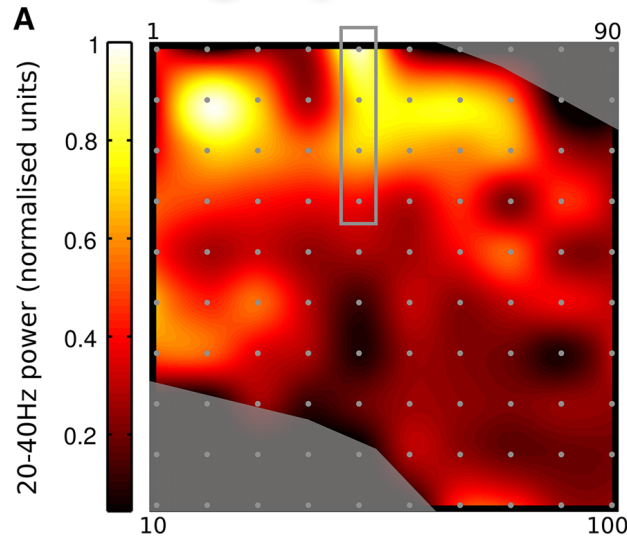
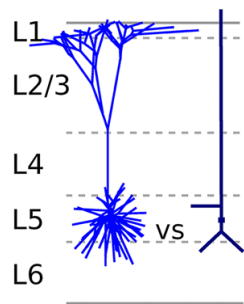
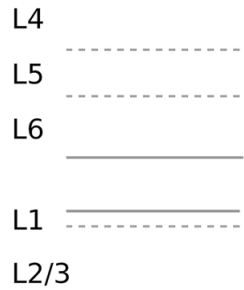
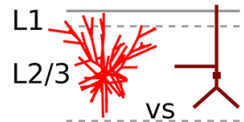


## Controlling Abnormal Network Dynamics with Optogenetics (CANDO)

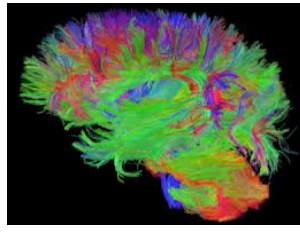
7yrs (till 2021), £10m [www.cando.ac.uk](http://www.cando.ac.uk)



# VERTEX: simulating dynamics within cortical columns



# Newcastle Institute of Neuroscience (IoN)



IoN: 100 faculty members in the neurosciences (many working with MRI, EEG, MEA)  
Human, rhesus monkey and rat *in vivo* and *in vitro* recordings

Host of the National Centre for Ageing Science and Innovation and  
National Institute for Smart Data Innovation (Big data, cloud computing)  
Parkinson's (motor system), hallucinations (visual system), HCI

Strategic priorities in Neurotechnology, Neuroimaging and Neuroinformatics

42 15 faculty members in Neuroinformatics and Neurotechnology  
**one open Neuroinformatics Lecturer/Senior Lecturer/Reader position later this year**

University Fellowships ("tenure-track" assistant professor position)

Faculty PhD studentships (including fees for EU students)

one-year MSc Neuroinformatics

<http://neuroinformatics.ncl.ac.uk/>

## Team

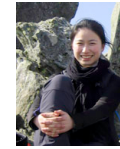
Luis Peraza  
PostDoc



Roman Bauer  
PostDoc → **faculty**



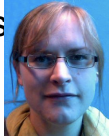
Yujiang Wang  
PostDoc → **faculty**



Michael Mackay  
PhD student



Frances Hutchings  
PhD student



Chris Hayward  
PhD student



Chris Pappasavvas  
PhD student



Chris Thornton  
PhD student



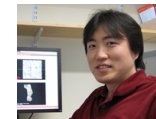
Sol Lim  
PostDoc



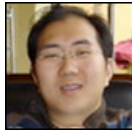
Peter Taylor  
Now **faculty**



Jinseop Kim  
Now **faculty**



Cheol Han  
Now **faculty**



### USA

Roger Traub, IBM/Columbia  
Olaf Sporns, Indiana-Bloomington  
Sydney Cash, Harvard

### Germany

Bernd Weber, Bonn  
Claus Hilgetag, Hamburg  
Marc-Thorsten Hütt, Bremen

### United Kingdom

Miles Whittington, York  
Stephen Eglon, Cambridge  
Stephen Jackson, Nottingham  
Peter Uhlhaas, Glasgow  
Steve Furber, Manchester

### South Korea

Joon-Kyung Seong, Korea Univ.  
Cheol Han, Korea Univ.  
Jinseop Kim, KBRI

### Brazil

Luciano da Fontoura Costa  
Bruno Mota

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<http://www.dynamic-connectome.org>



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