"When" on Macro-Connectome and Communicability

17'/06/20

Masanori Shimono

OSAKA UNIVERSITY

Brain Science Institute RIKEN

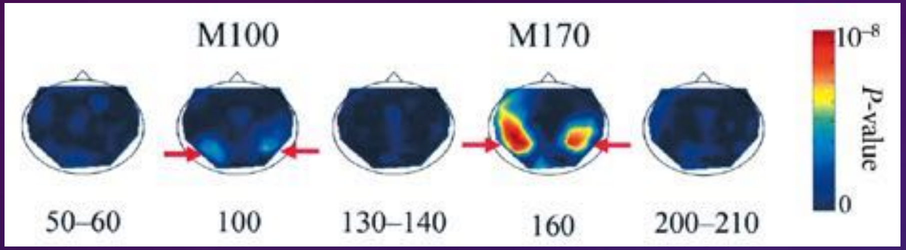
RIKEN

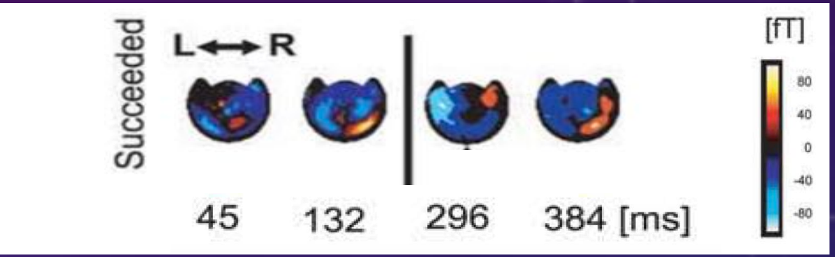
How “When” of Neurodynamics is determined ?

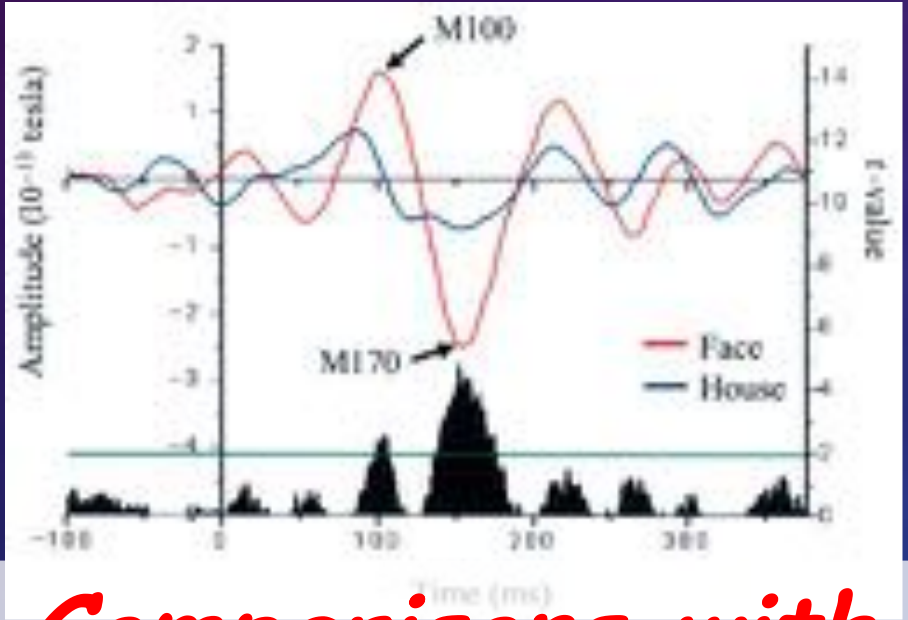
"When" of Neurodynamics

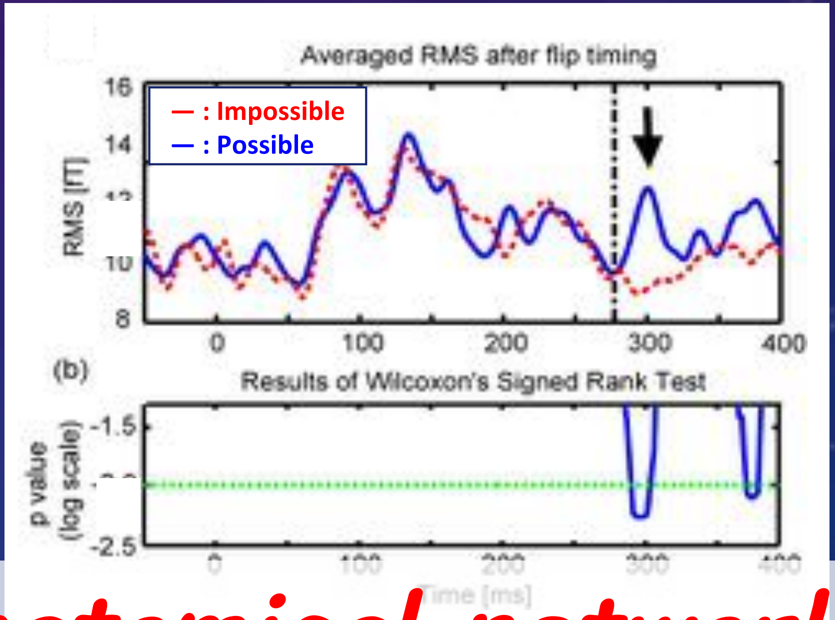
e.g.1) M/N170 for M/EEG

e.g.2) M/P300 for M/EEG









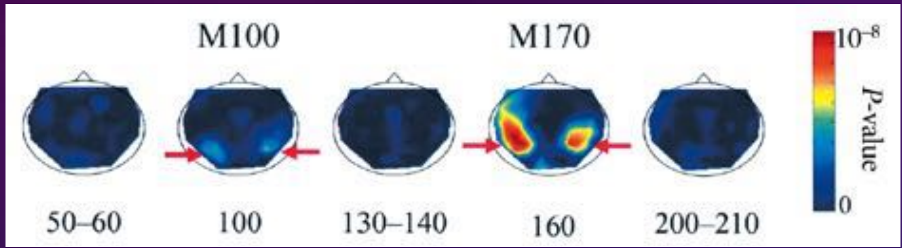
Comparisons with anatomical networks are necessary!!

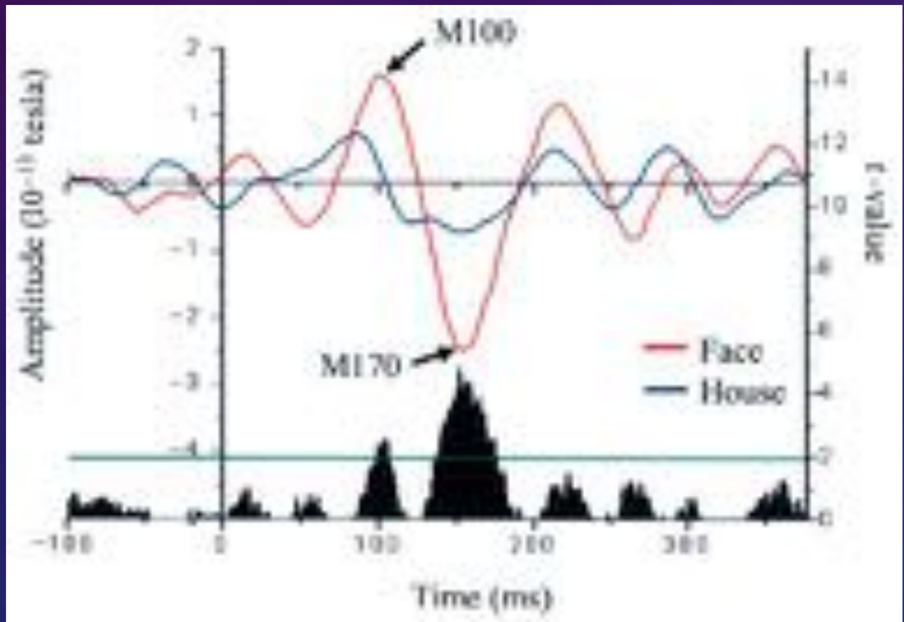
Liu, et al. (2002)

Chapman, Bragdon (1964), Shimono, et al. (2011)

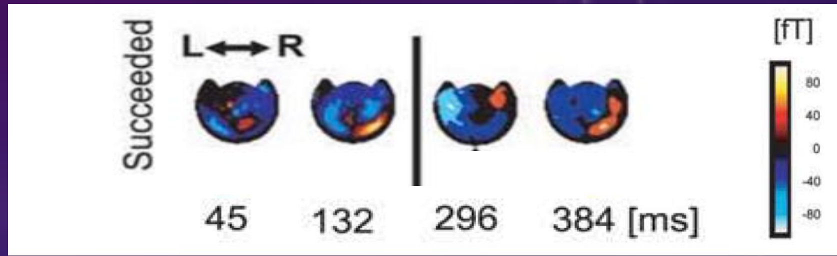
"When" of Neurodynamics

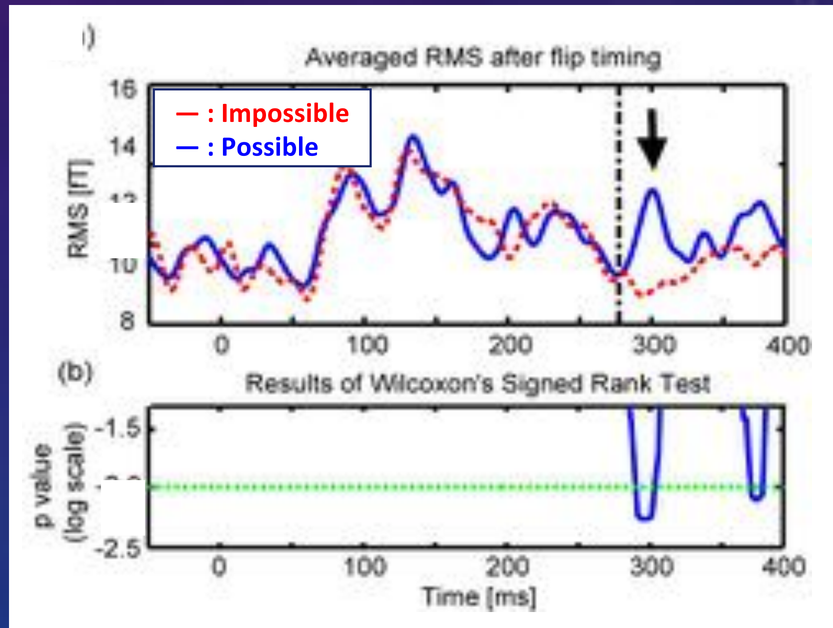
e.g.1) M/N170 for M/EEG





e.g.2) M/P300 for M/EEG



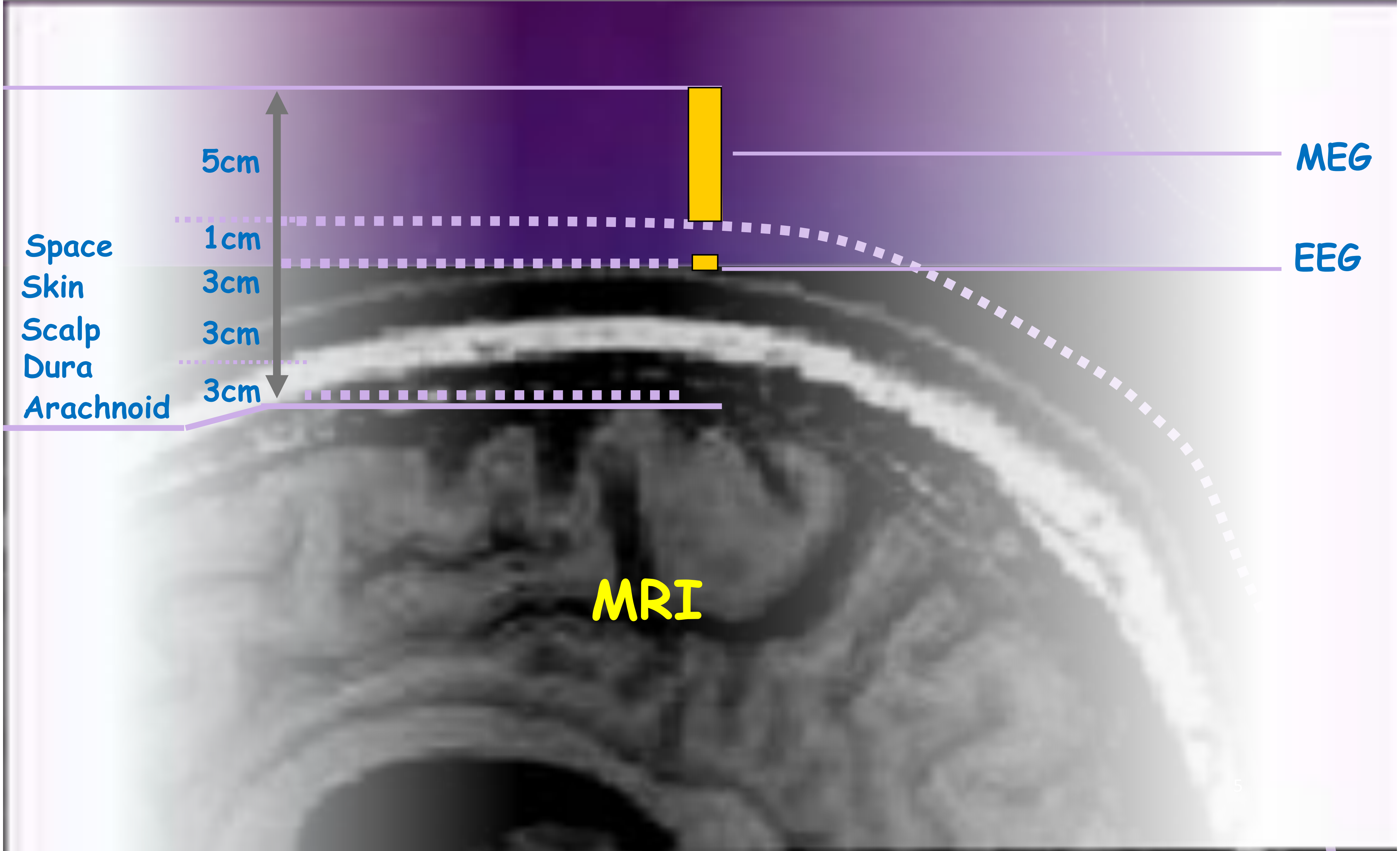


Many paths should exist!!

Liu, et al. (2002)

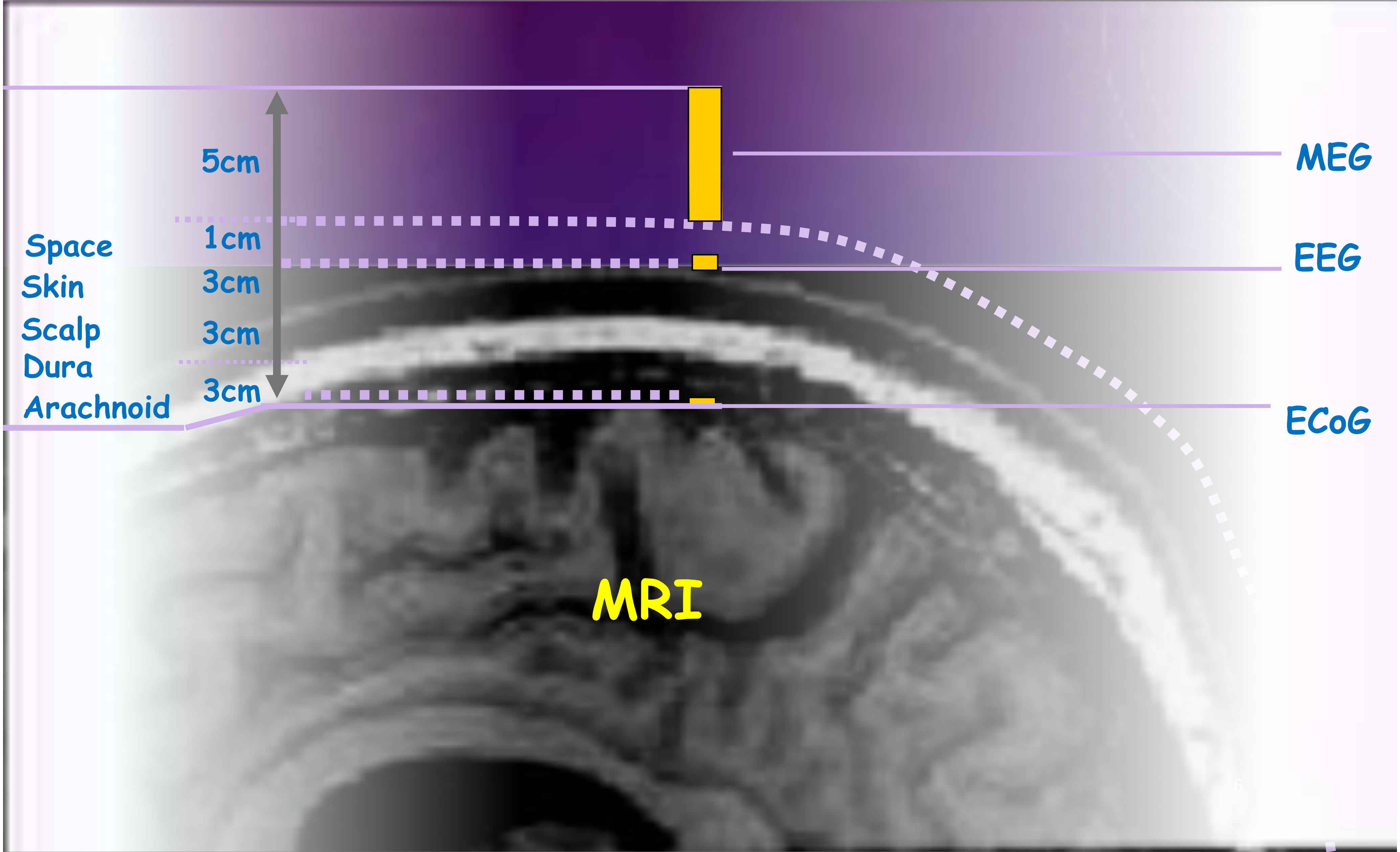
Chapman, Bragdon (1964), Shimono, et al. (2011)

Various brain-recording technologies



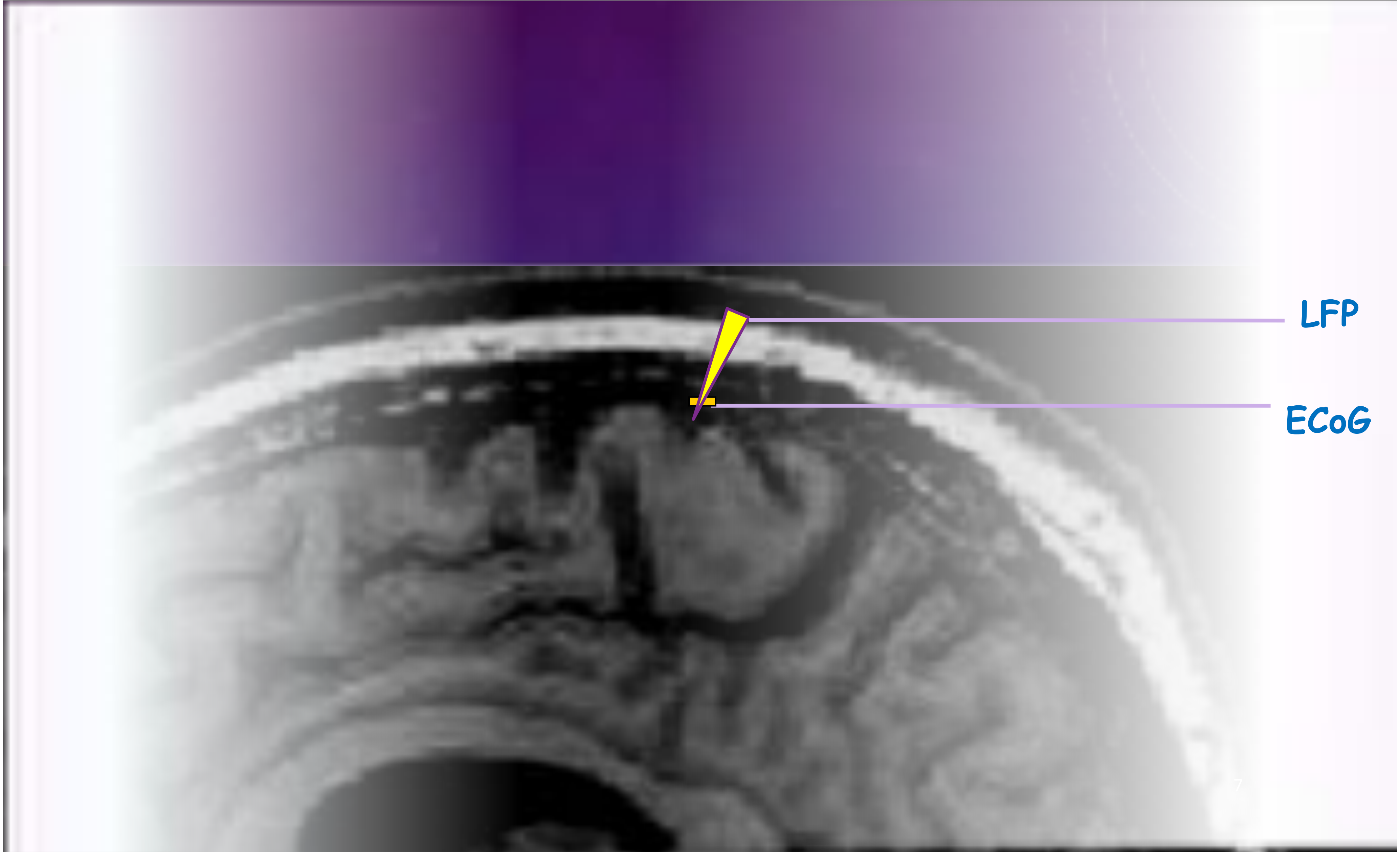
Shimono, Hatano (2016)

Various brain-recording technologies



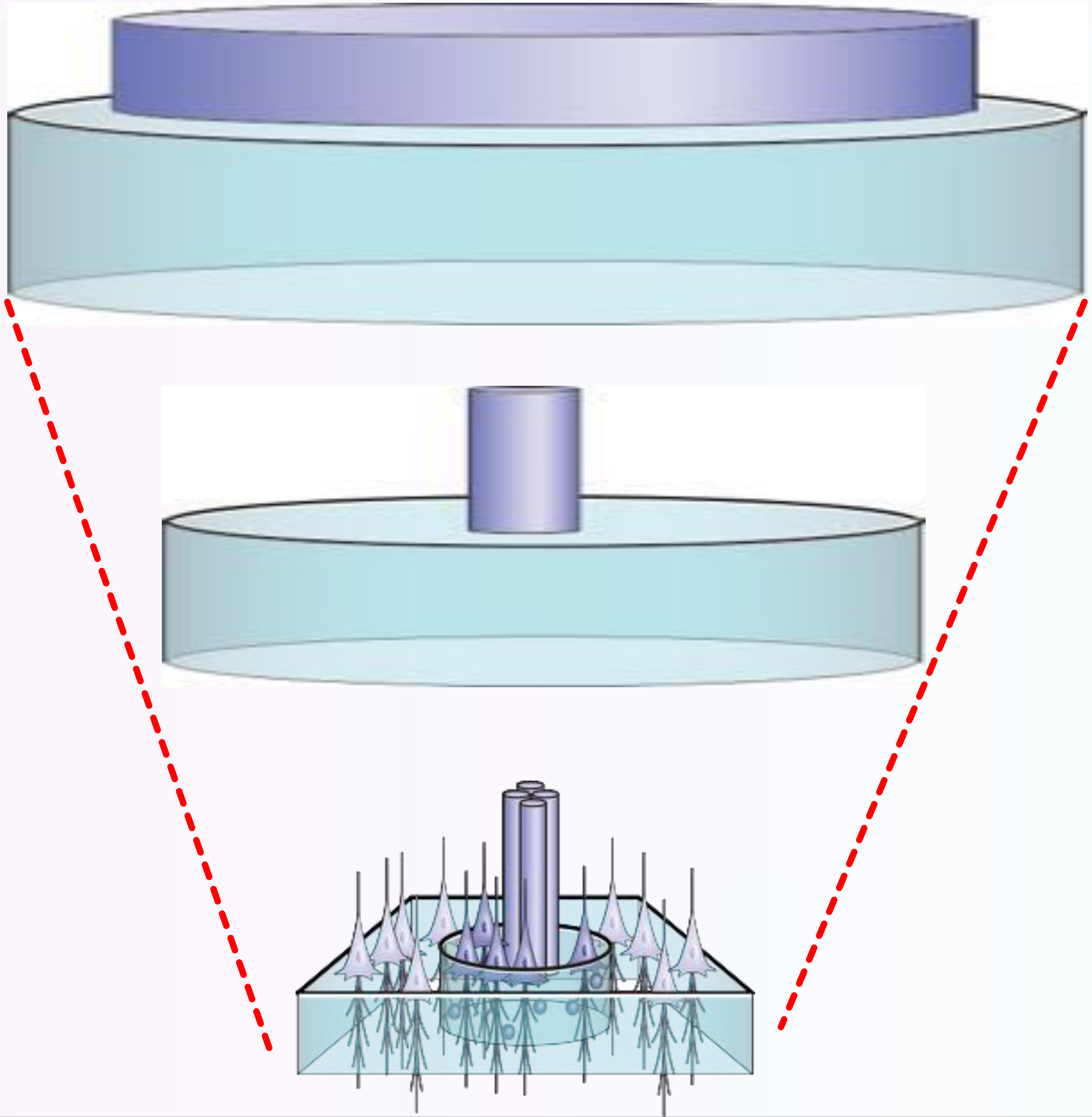
Shimono, Hatano (2016)

Various brain-recording technologies



Shimono, Hatano (2016)

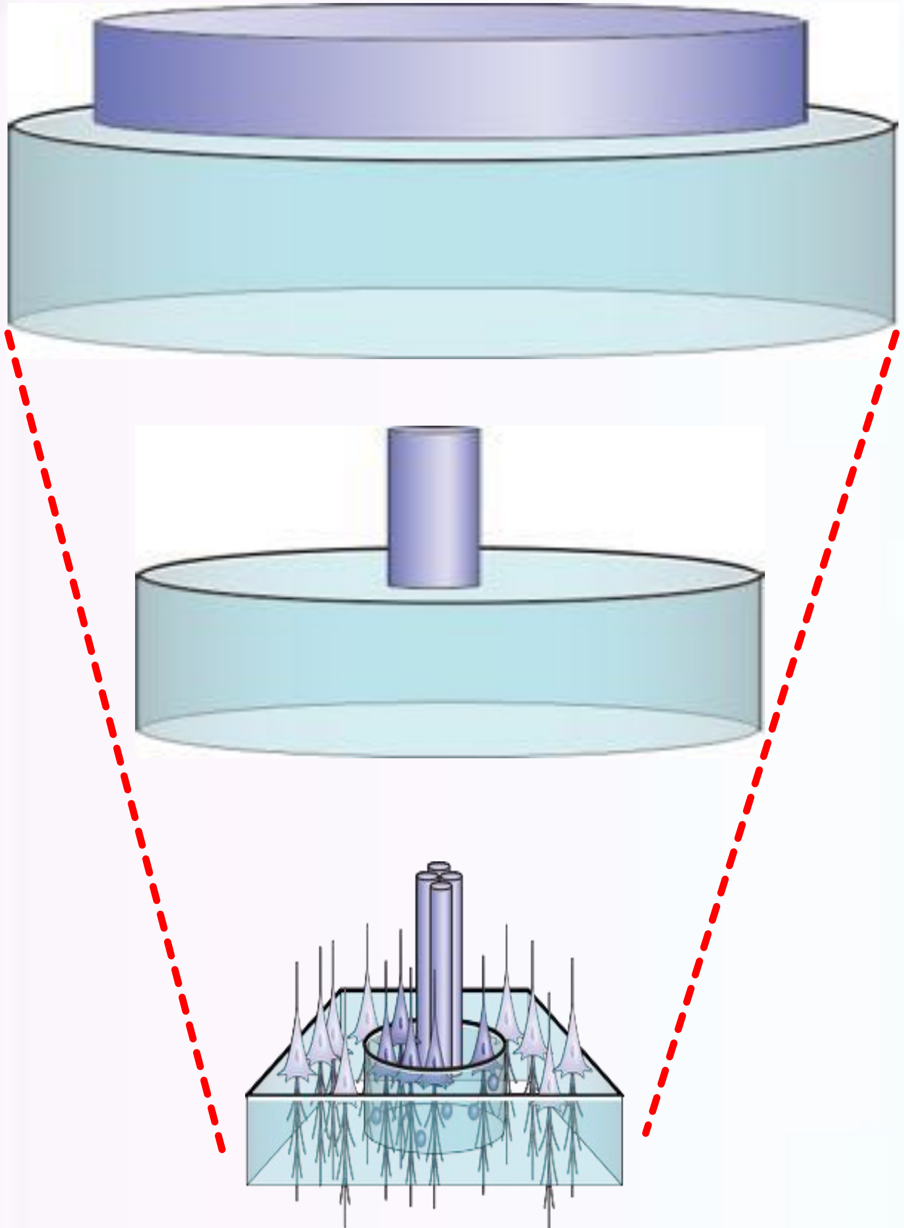
Various brain-recording technologies



	Resolution
ECoG	Region ~1 cm
LFP	~1 mm
S/MUA	Neuron ~1 µm

Shimono, Hatano (2016)

Various brain-recording technologies

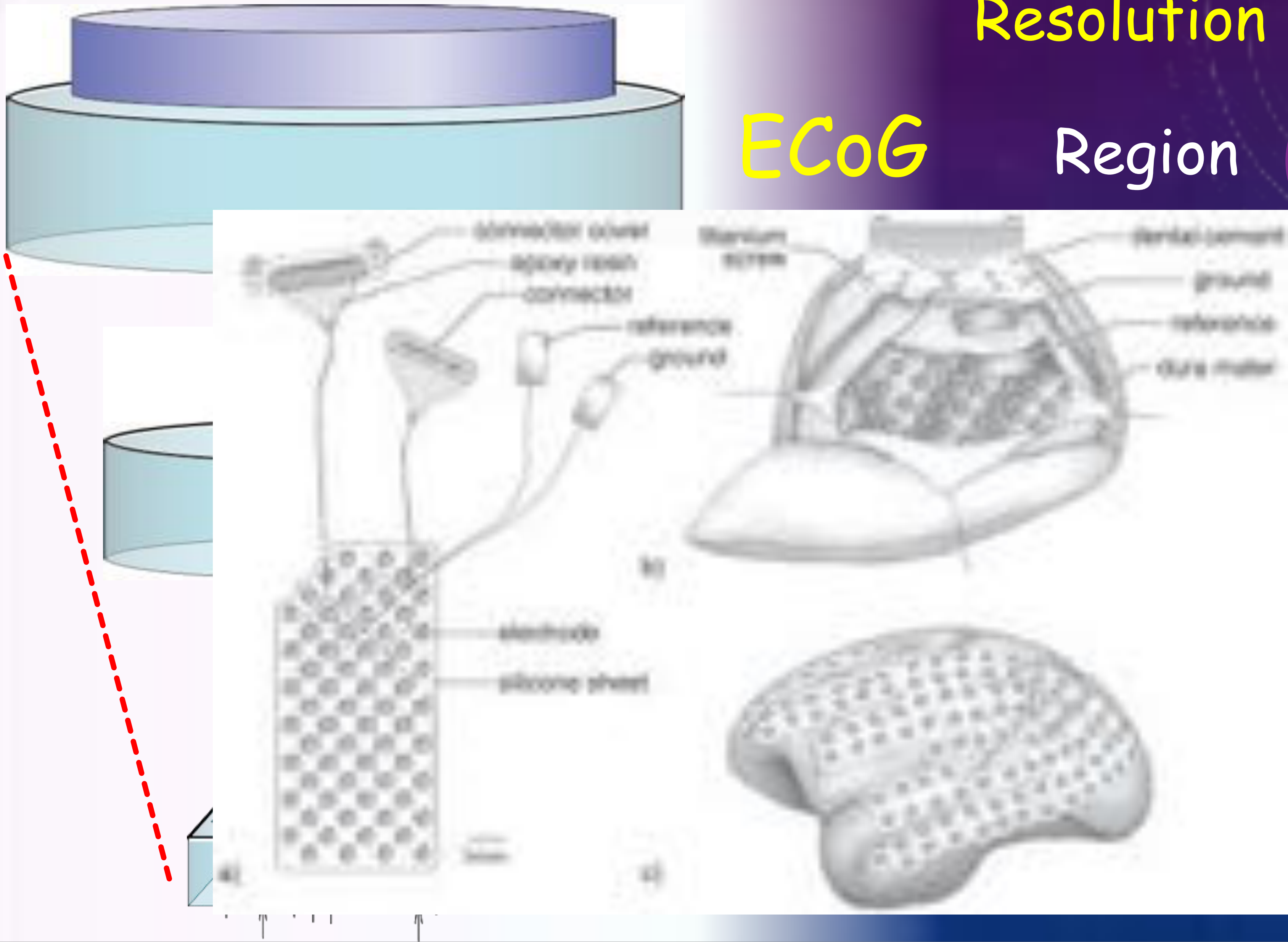


	Resolution	Range
ECoG	Region ~1 cm	Brain wide
LFP	~1 mm	
S/MUA	Neuron ~1 µm	Local

Shimono, Hatano (2016)

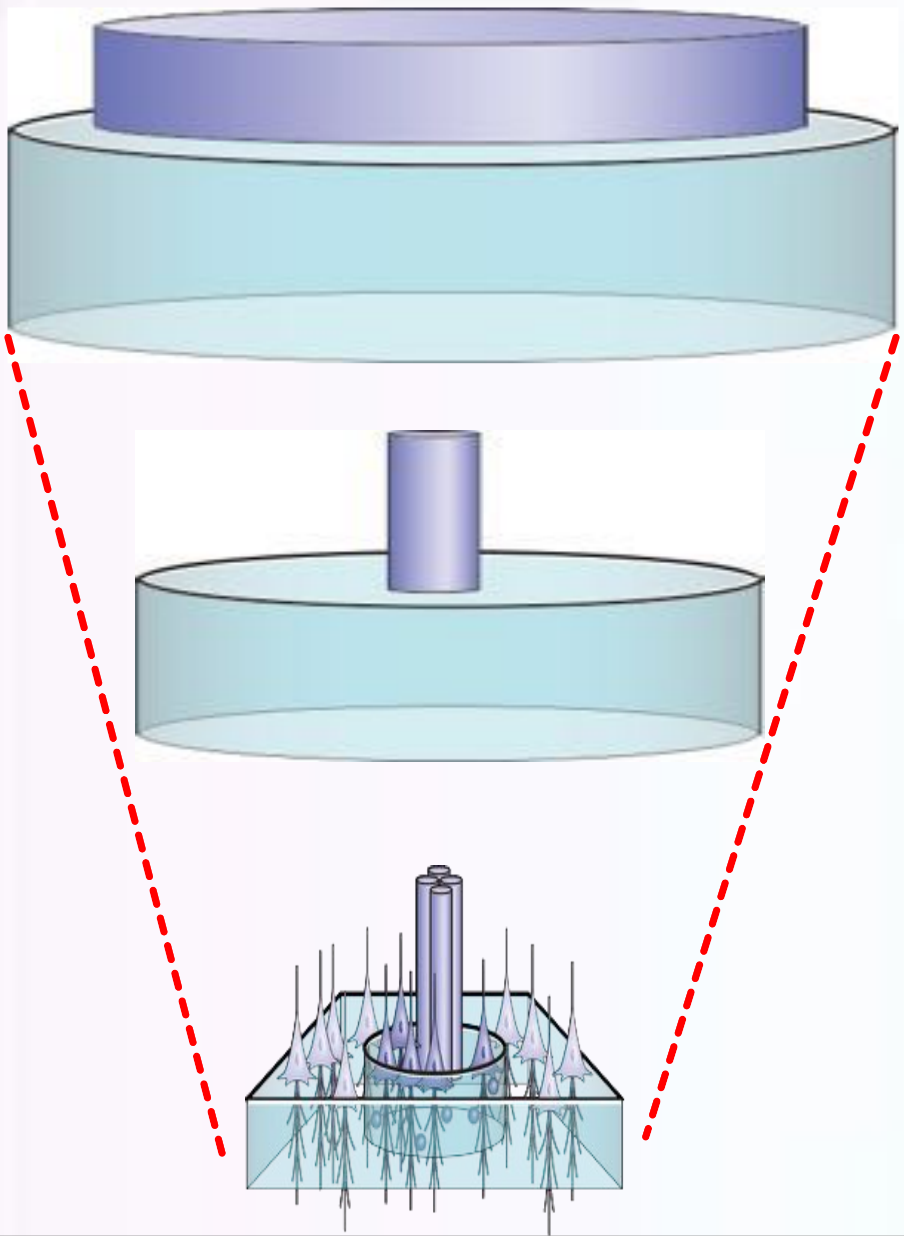
Various brain-recording technologies

	Resolution	Range
ECoG	Region	Brain wide
		Local



Nagasaka et al. (2011)

Various brain-recording technologies



	Resolution	Range
ECoG	Region ~1 cm	Brain wide
LFP		
S/MUA	Neuron ~1 µm	Local

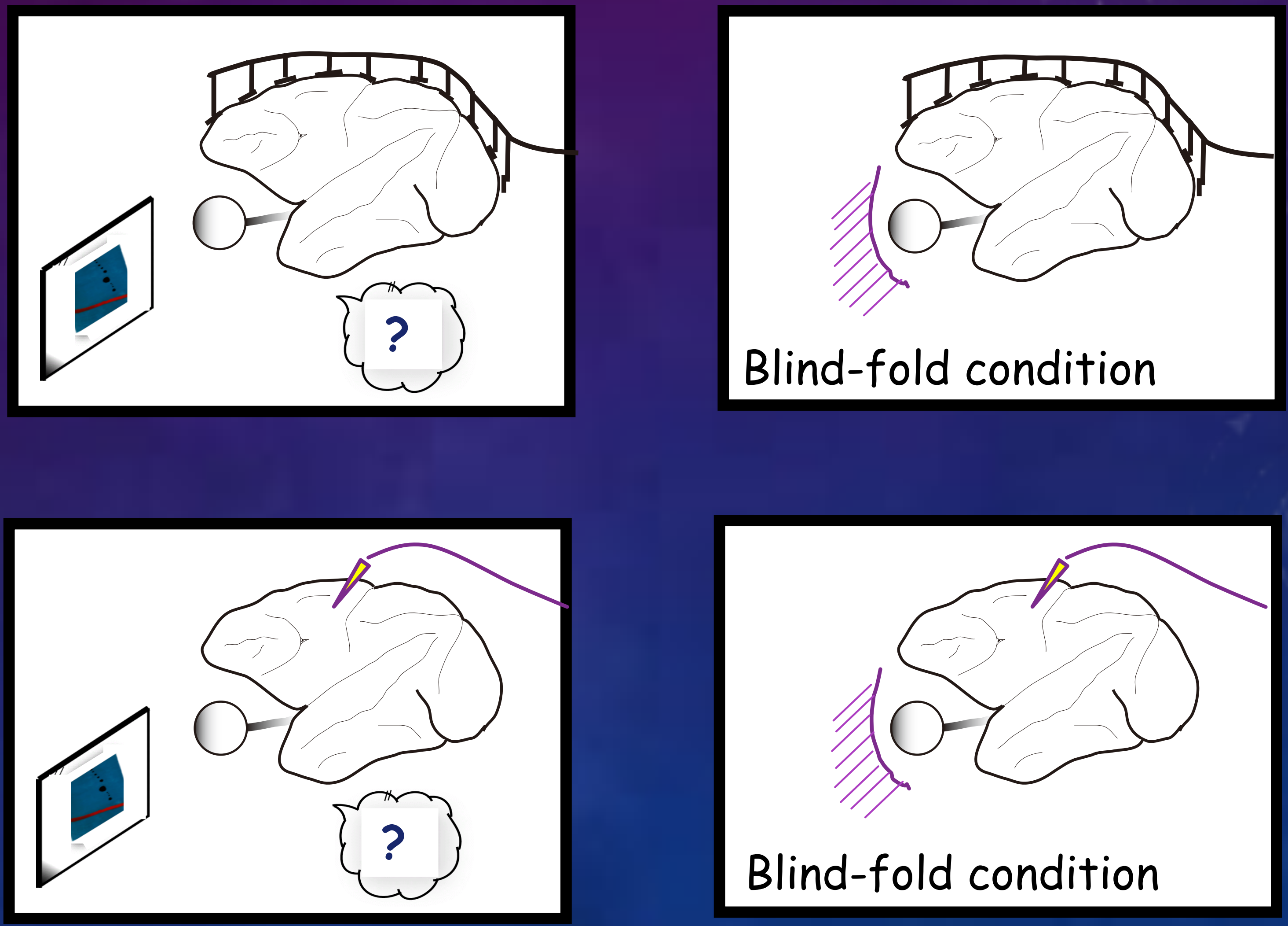
Shimono, Hatano (2016)

Evoked response & Spontaneous activity

Evoked response | Spontaneous activity

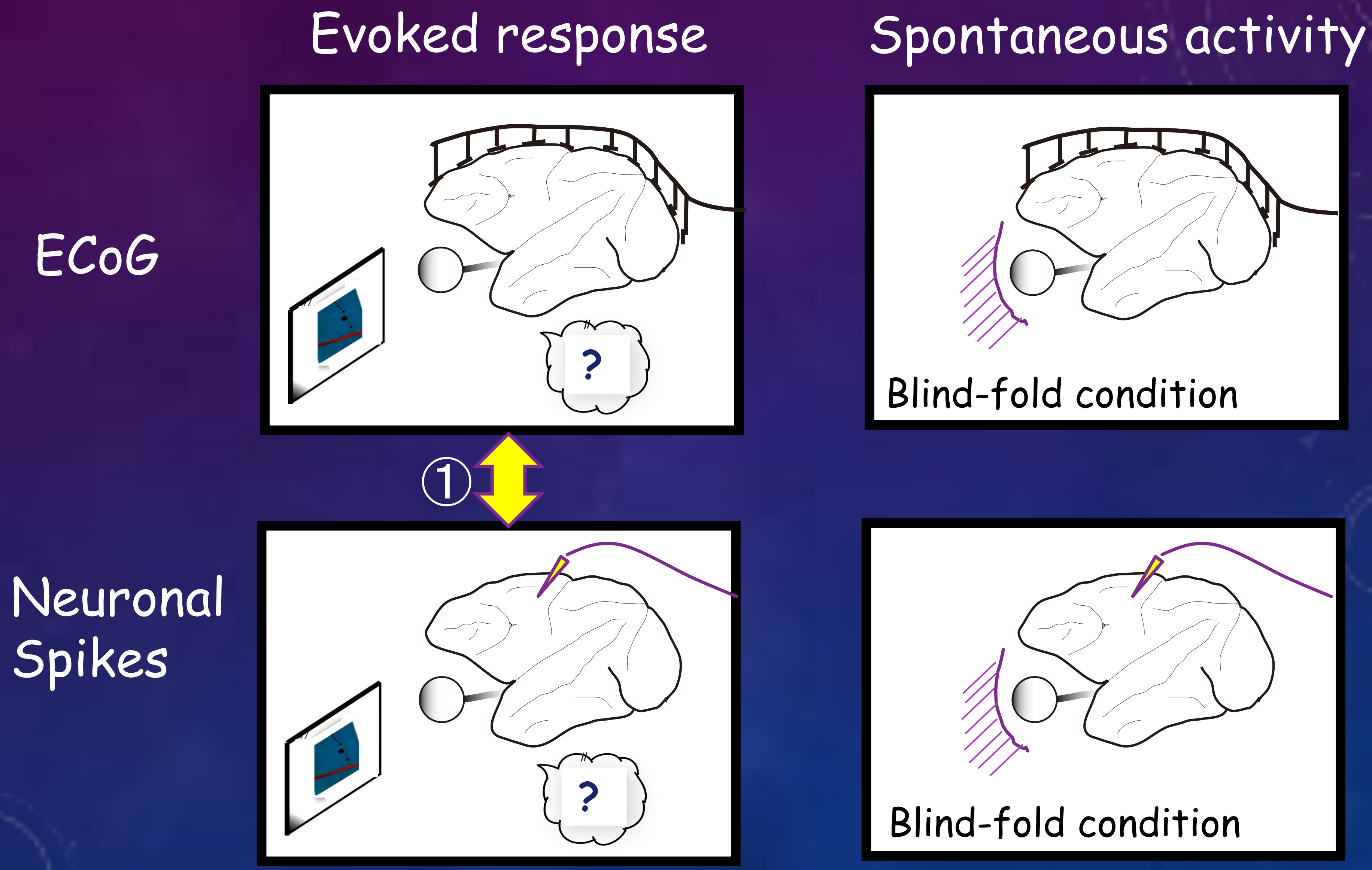
ECoG

Neuronal Spikes



Shimono, Hatano (2016)

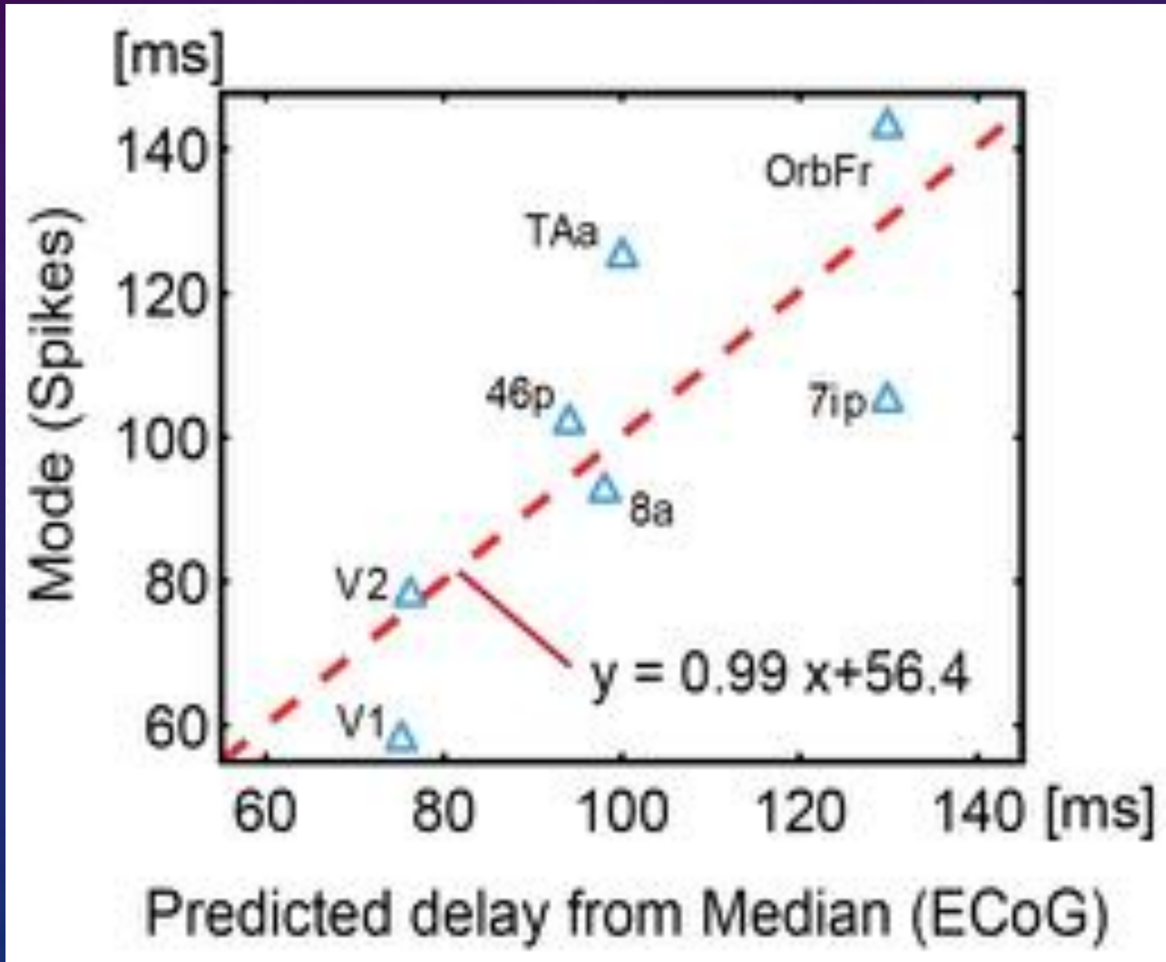
Evoked response & Spontaneous activity



Shimono, Hatano (2016)

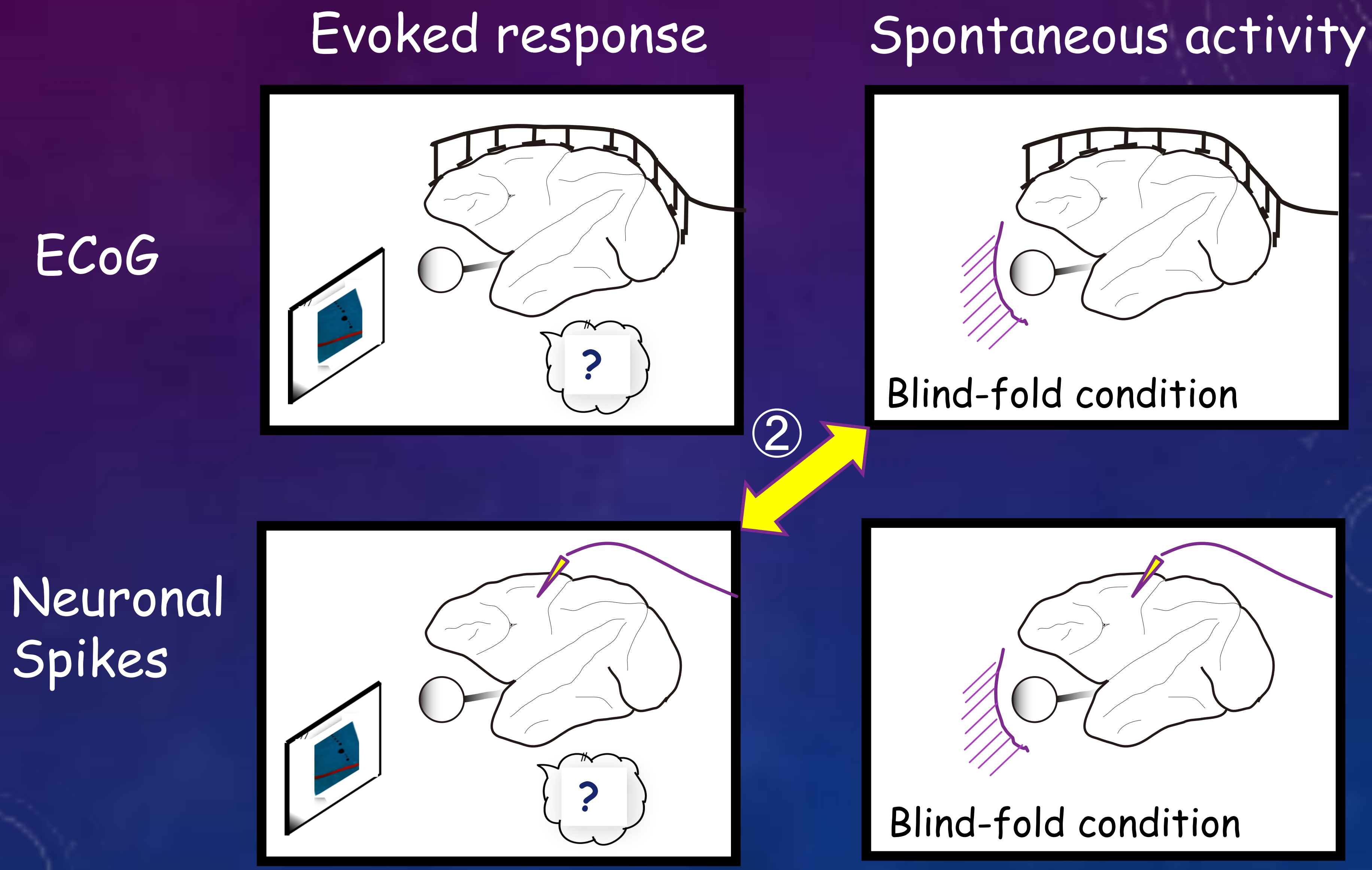
ECoG (Evoked) vs. Spikes (Evoked)

ECoG can predict neuronal spike delays within evoked conditions.



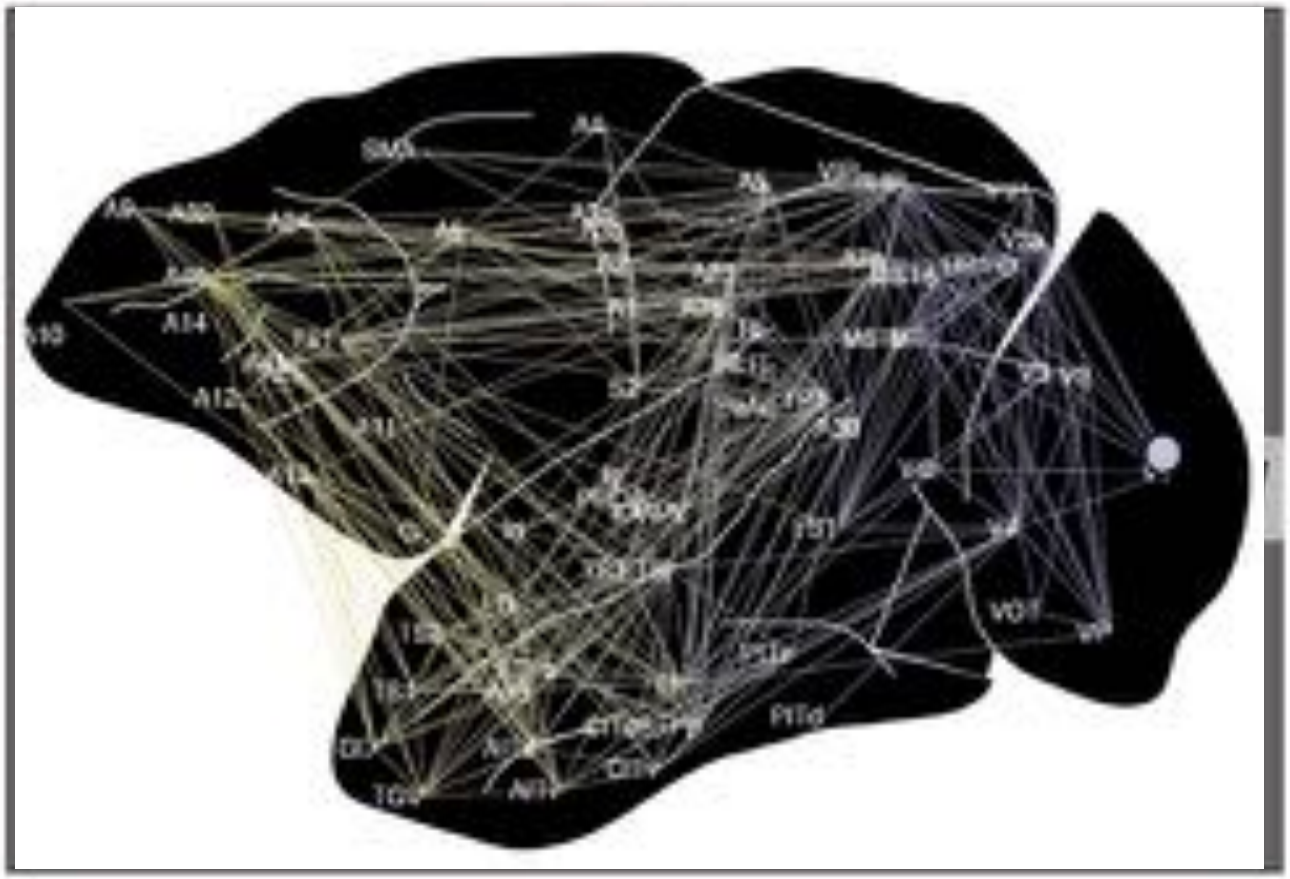
Shimono, Hatano (2016)

Evoked response & Spontaneous activity



Shimono, Hatano (2016)

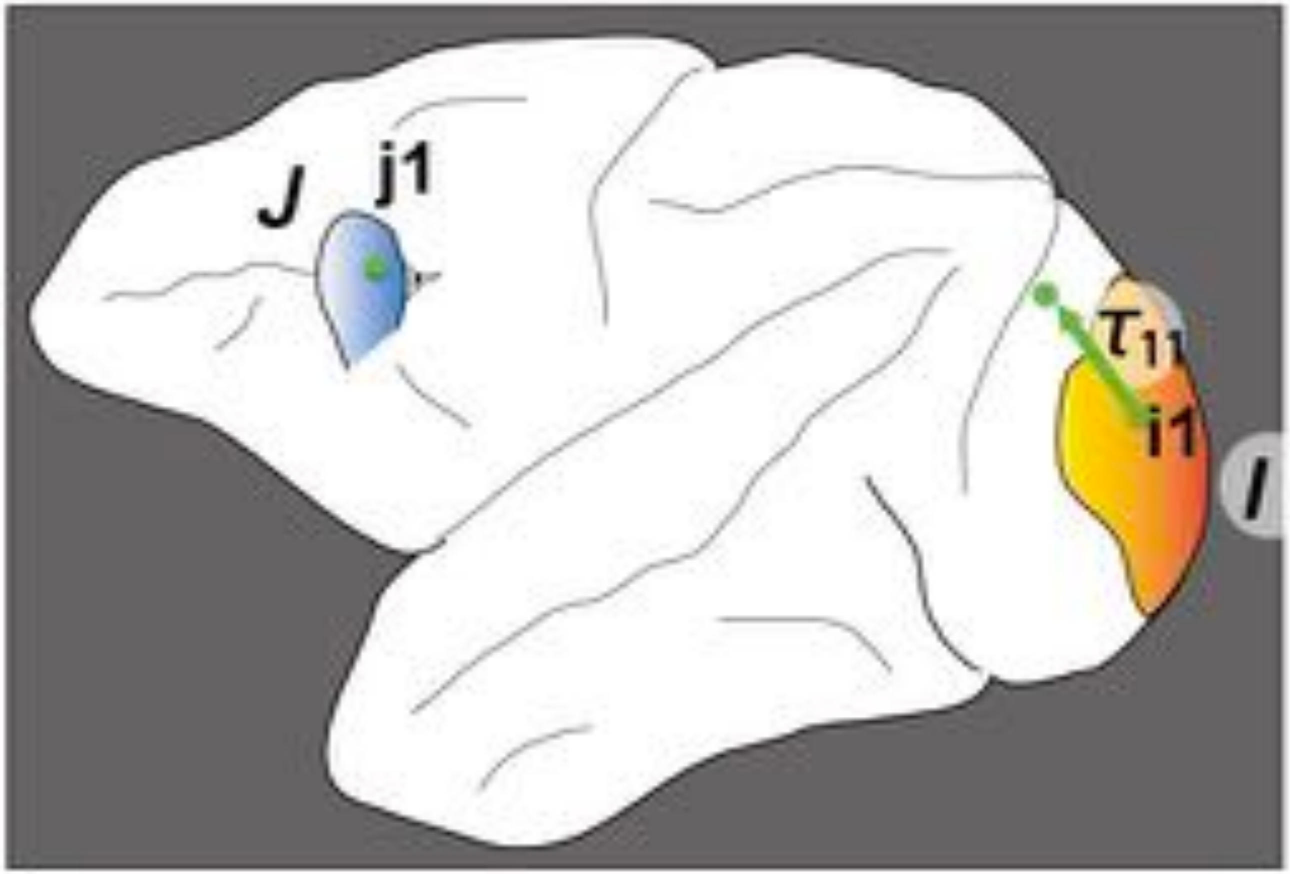
ECoG (Spontaneous) vs. Spikes (Evoked)



Structural constraint

Trace Injection data

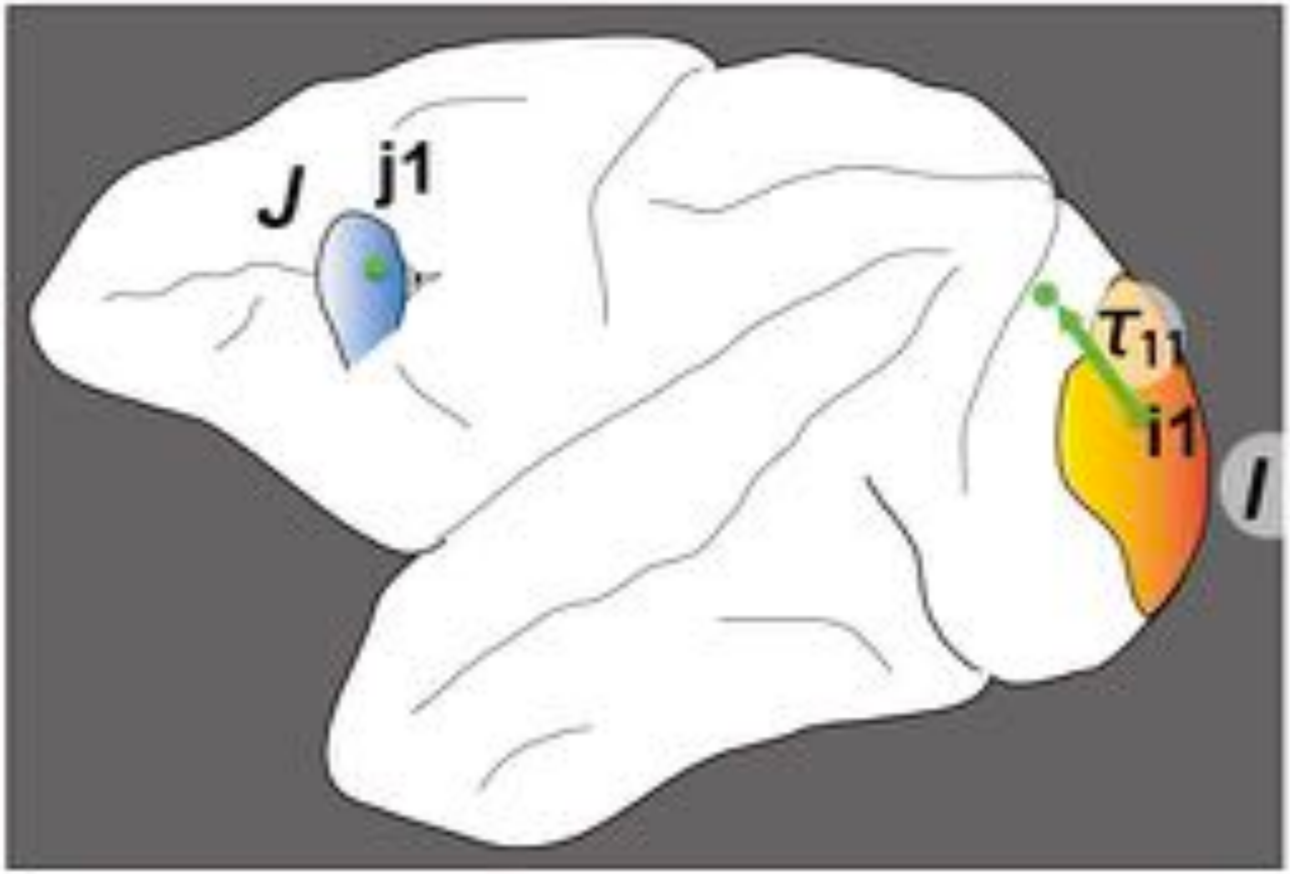
ECoG (Spontaneous) vs. Spikes (Evoked)



$$\tau_{(path\ index)(walk\ step)}$$

Shimono, Hatano (2016)

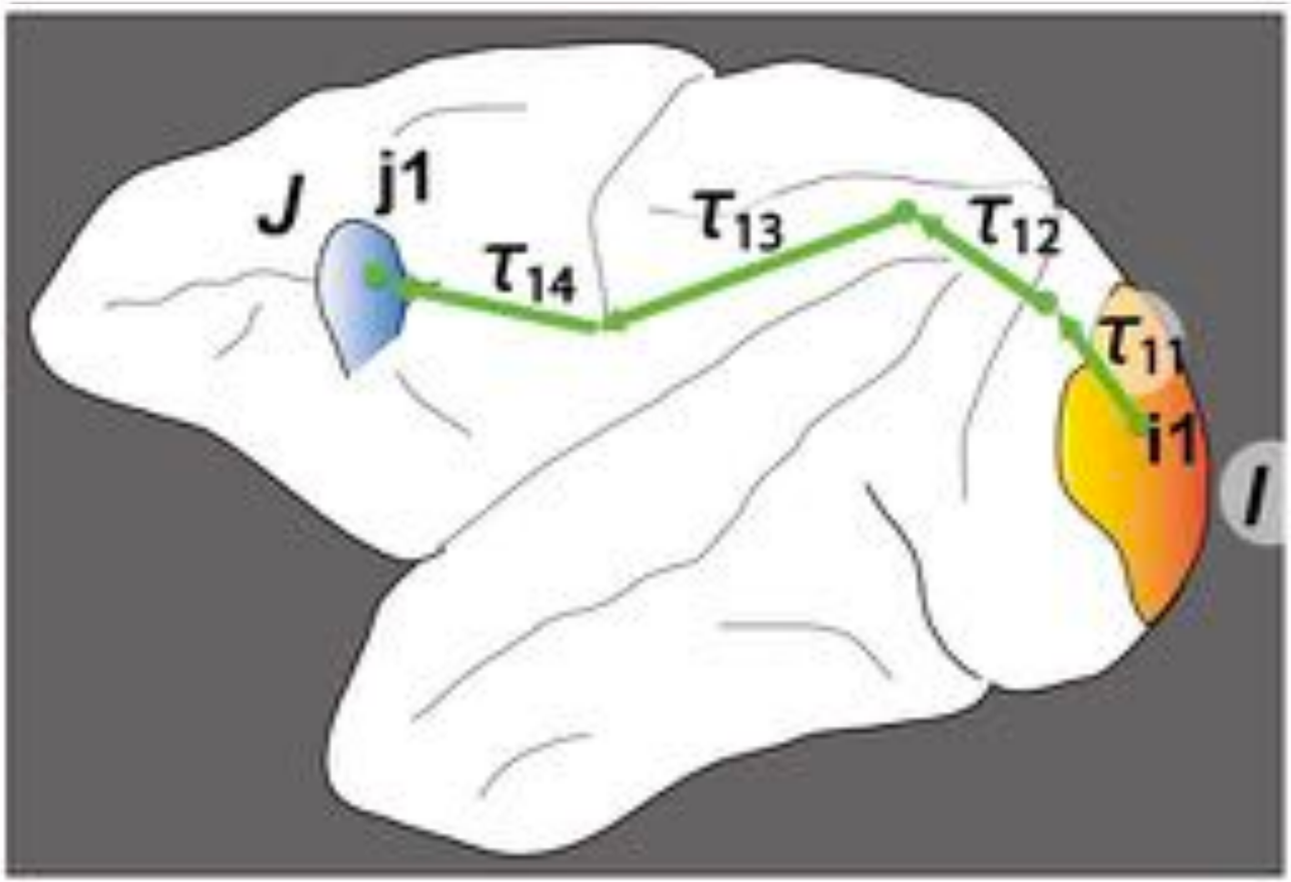
ECoG (Spontaneous) vs. Spikes (Evoked)



A first Walk step:

τ_{11}

ECoG (Spontaneous) vs. Spikes (Evoked)

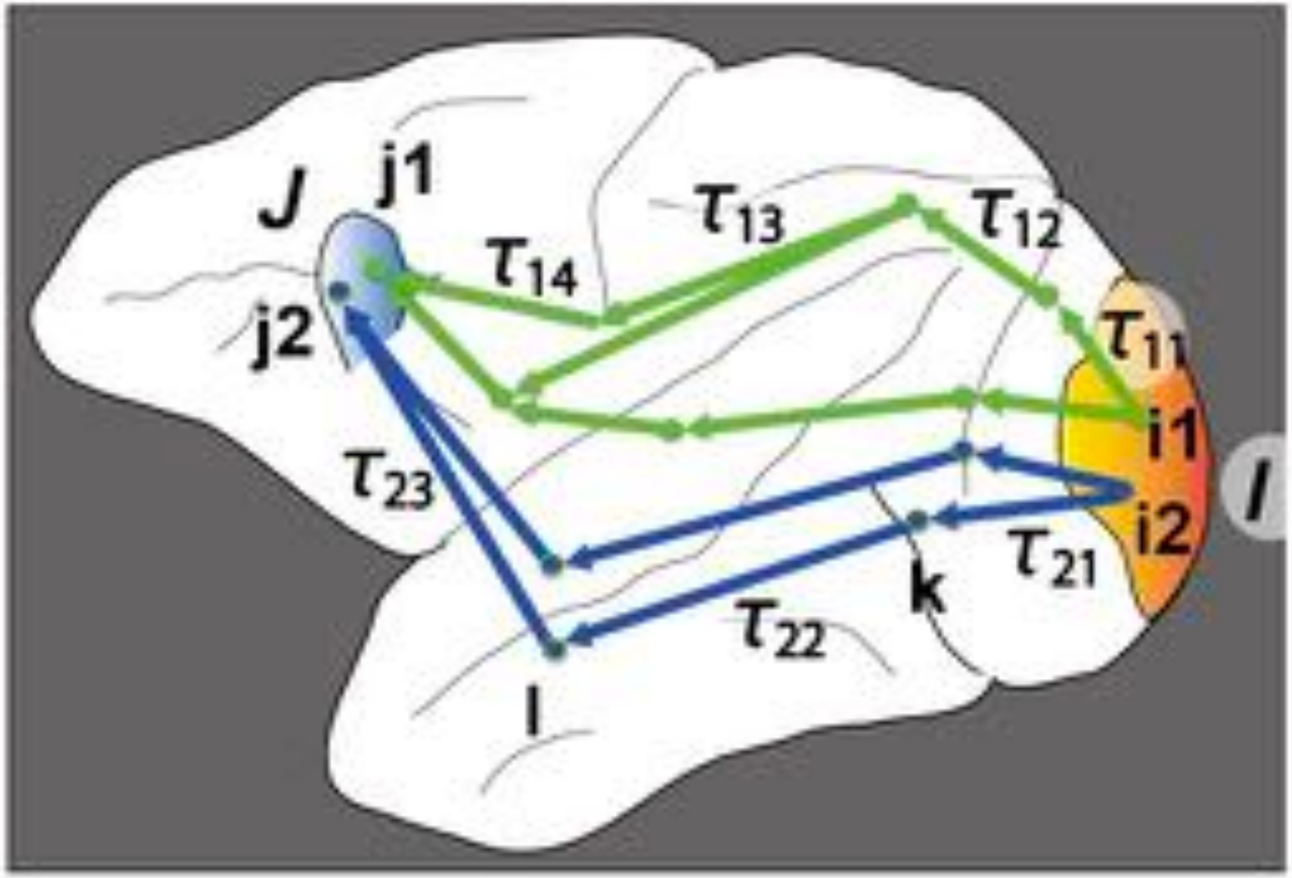


On one path:

$$\tau_{11} + \tau_{12} + \tau_{13} + \tau_{14} = \tau_1$$

Shimono, Hatano (2016)

ECoG (Spontaneous) vs. Spikes (Evoked)

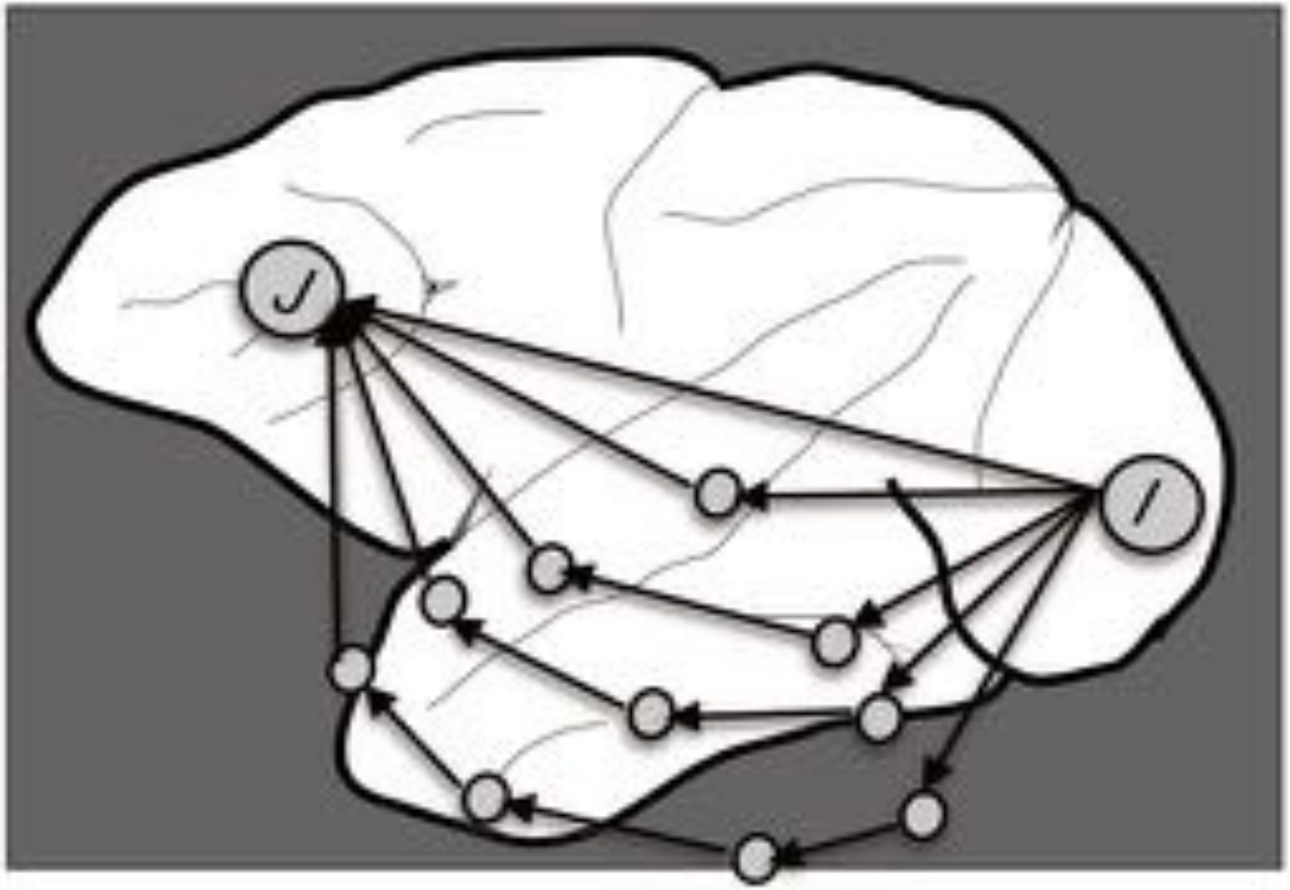


Many paths exist!!

$\tau_1, \tau_2, \tau_3, \tau_4, \ldots$

Shimono, Hatano (2016)

ECoG (Spontaneous) vs. Spikes (Evoked)

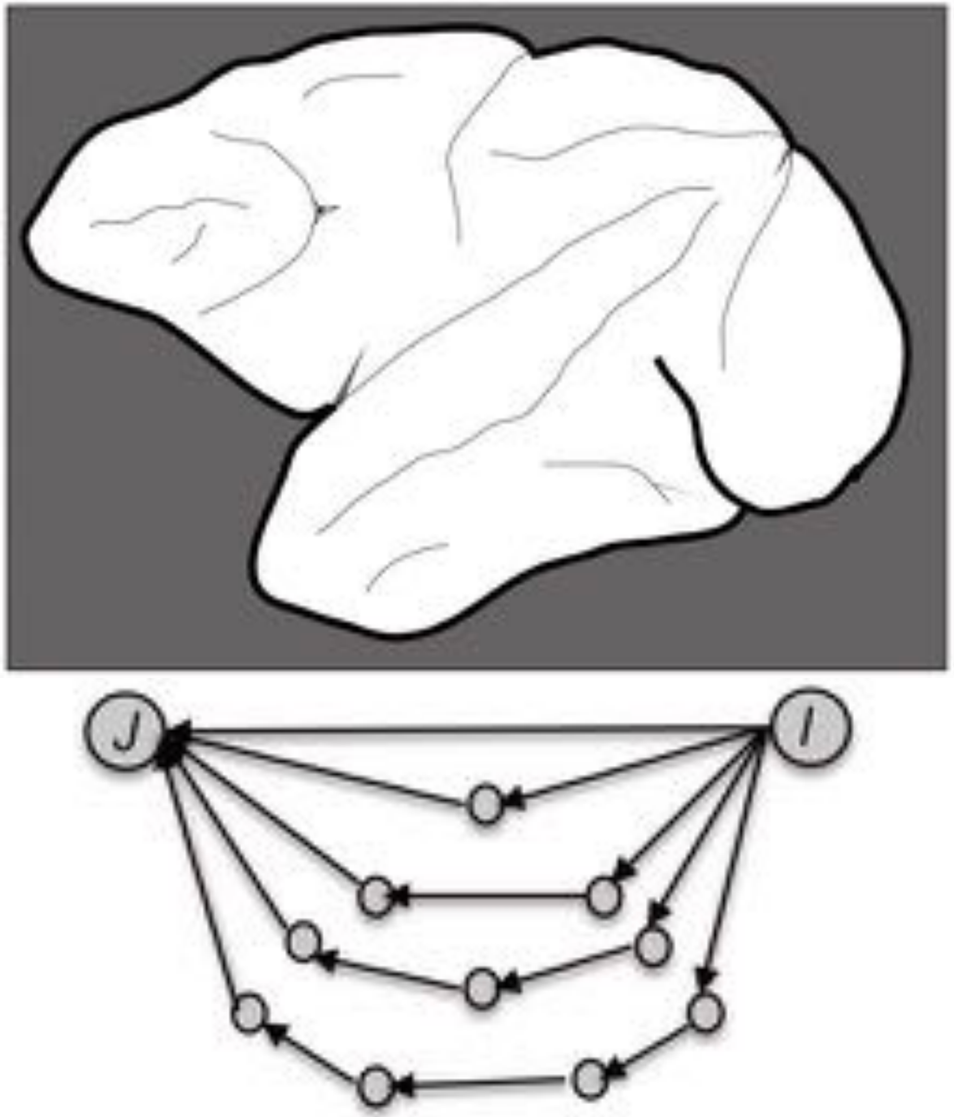


We categorized paths depending on Walk steps.

Shimono, Hatano (2016)

ECoG (Spontaneous) vs. Spikes (Evoked)

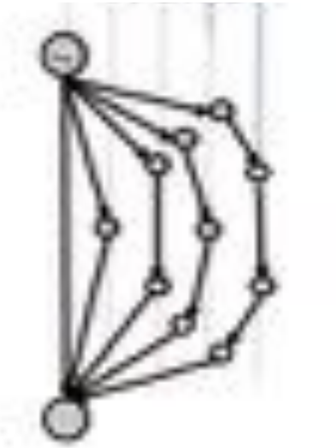
And…



Shimono, Hatano (2016)

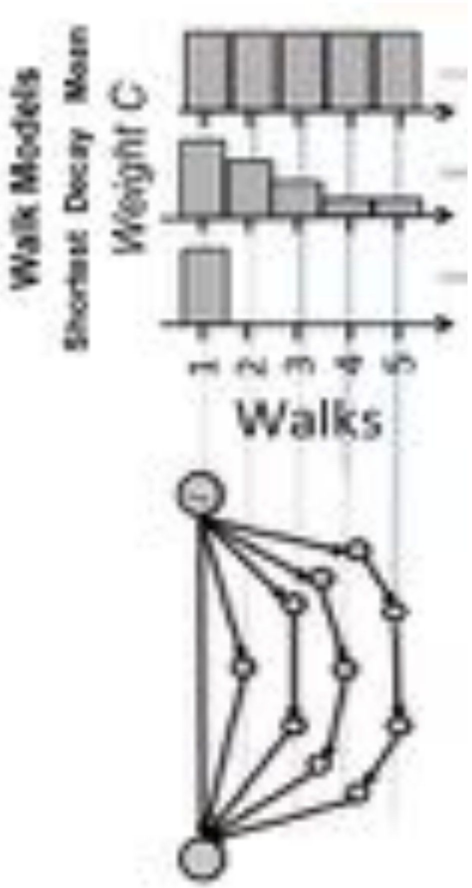
ECoG (Spontaneous) vs. Spikes (Evoked)

And…



Shimono, Hatano (2016)

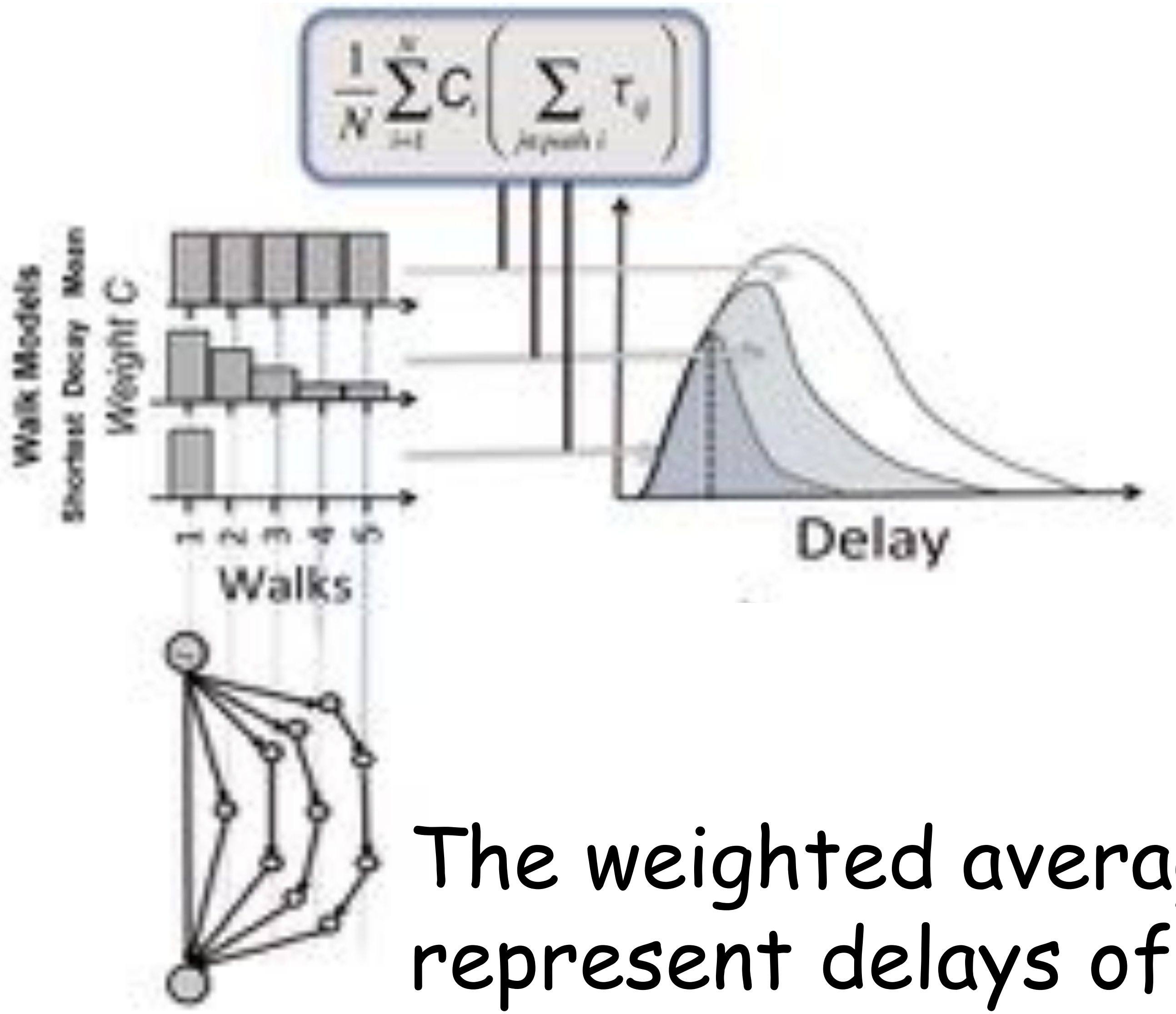
ECoG (Spontaneous) vs. Spikes (Evoked)



We defined weight C (decay index) depending on Walk steps.

Shimono, Hatano (2016)

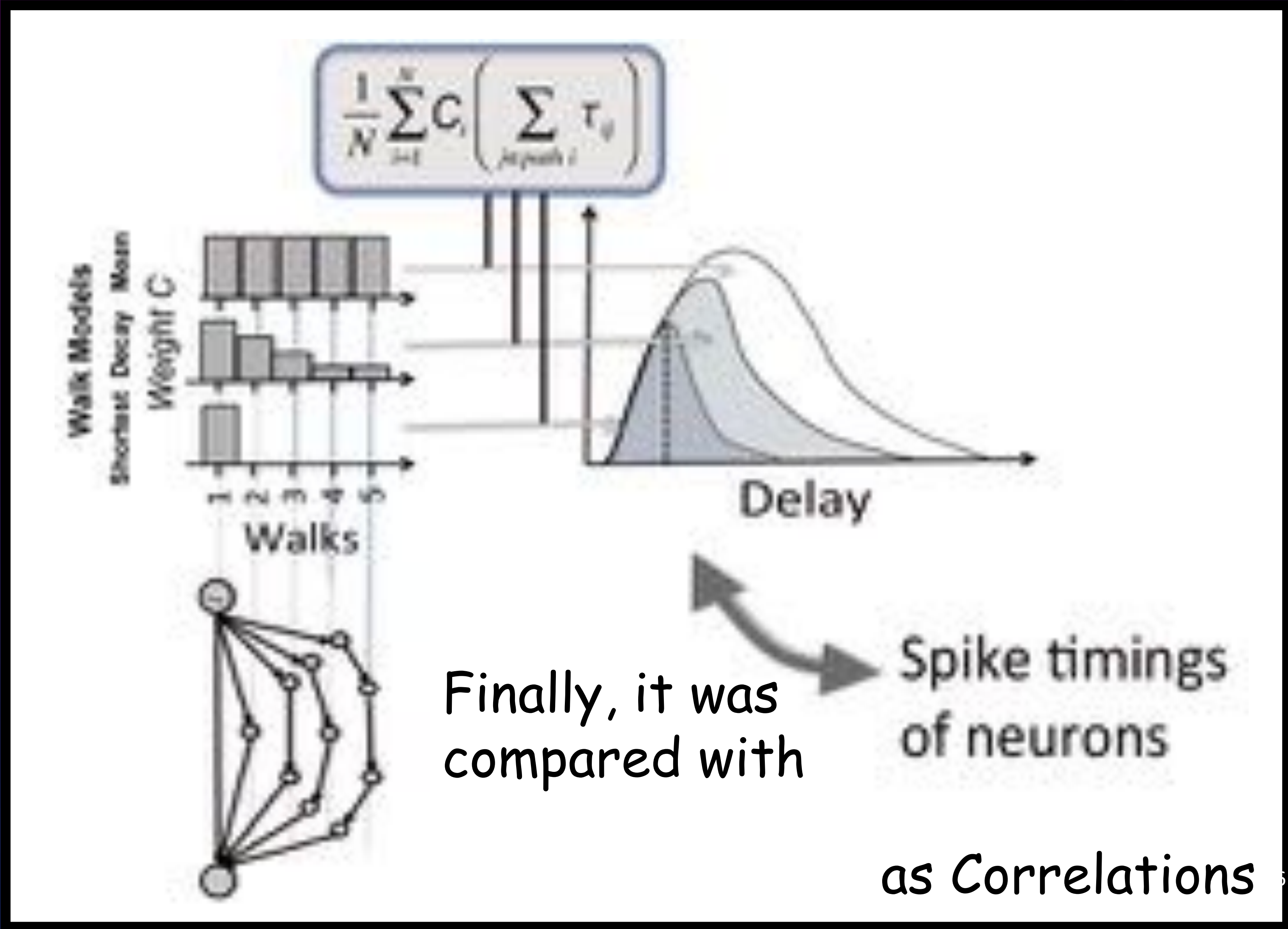
ECoG (Spontaneous) vs. Spikes (Evoked)



The weighted averages represent delays of ECoG.

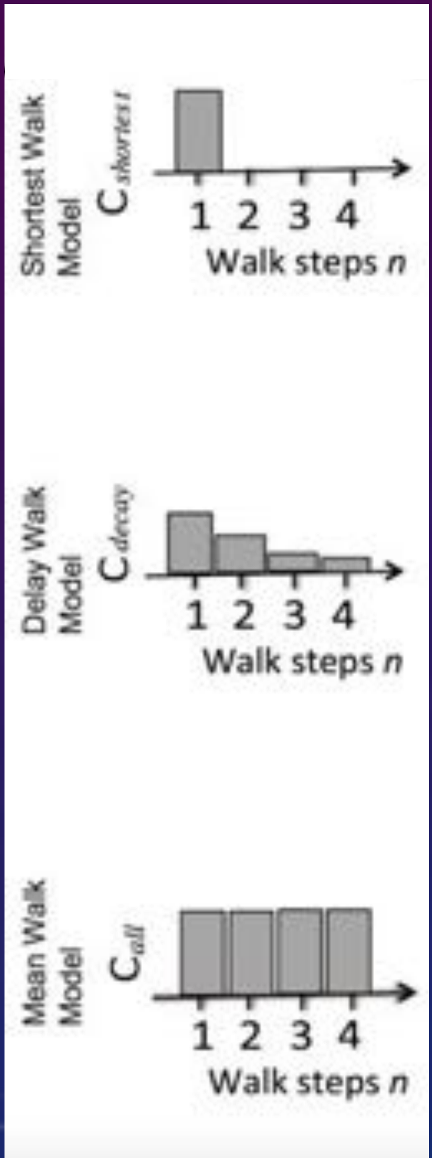
Shimono, Hatano (2016)

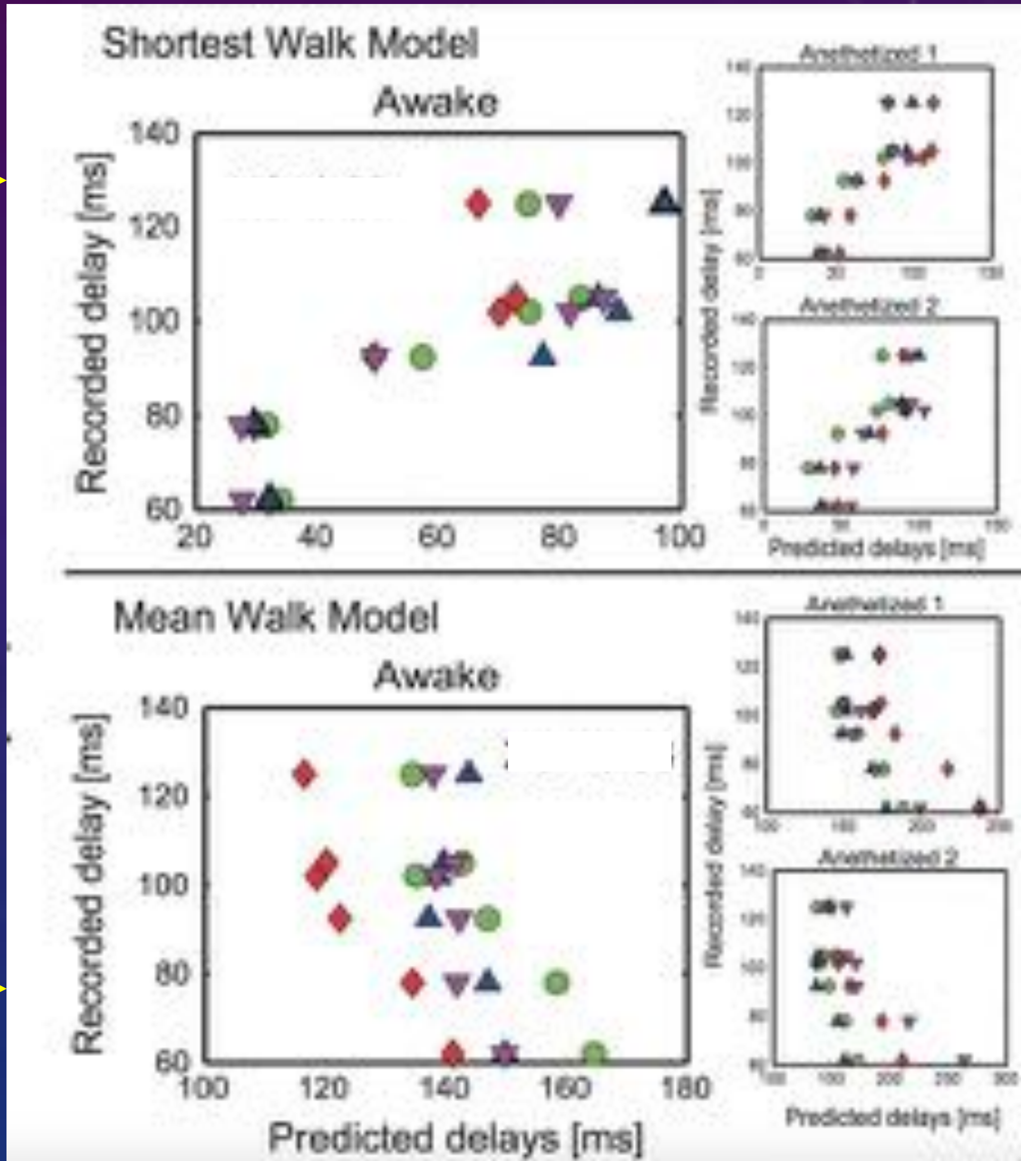
ECoG (Spontaneous) vs. Spikes (Evoked)



Shimono, Hatano (2016)

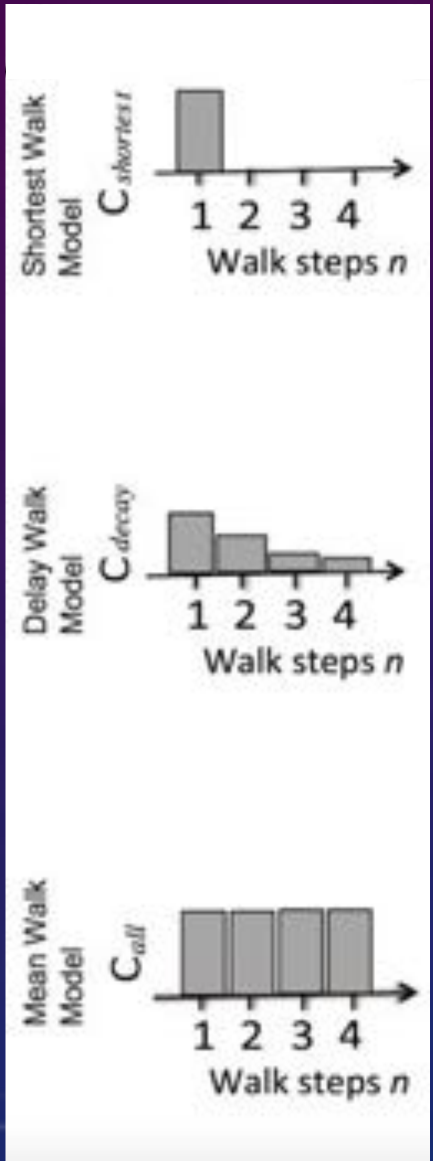
Contribution of indirect connections

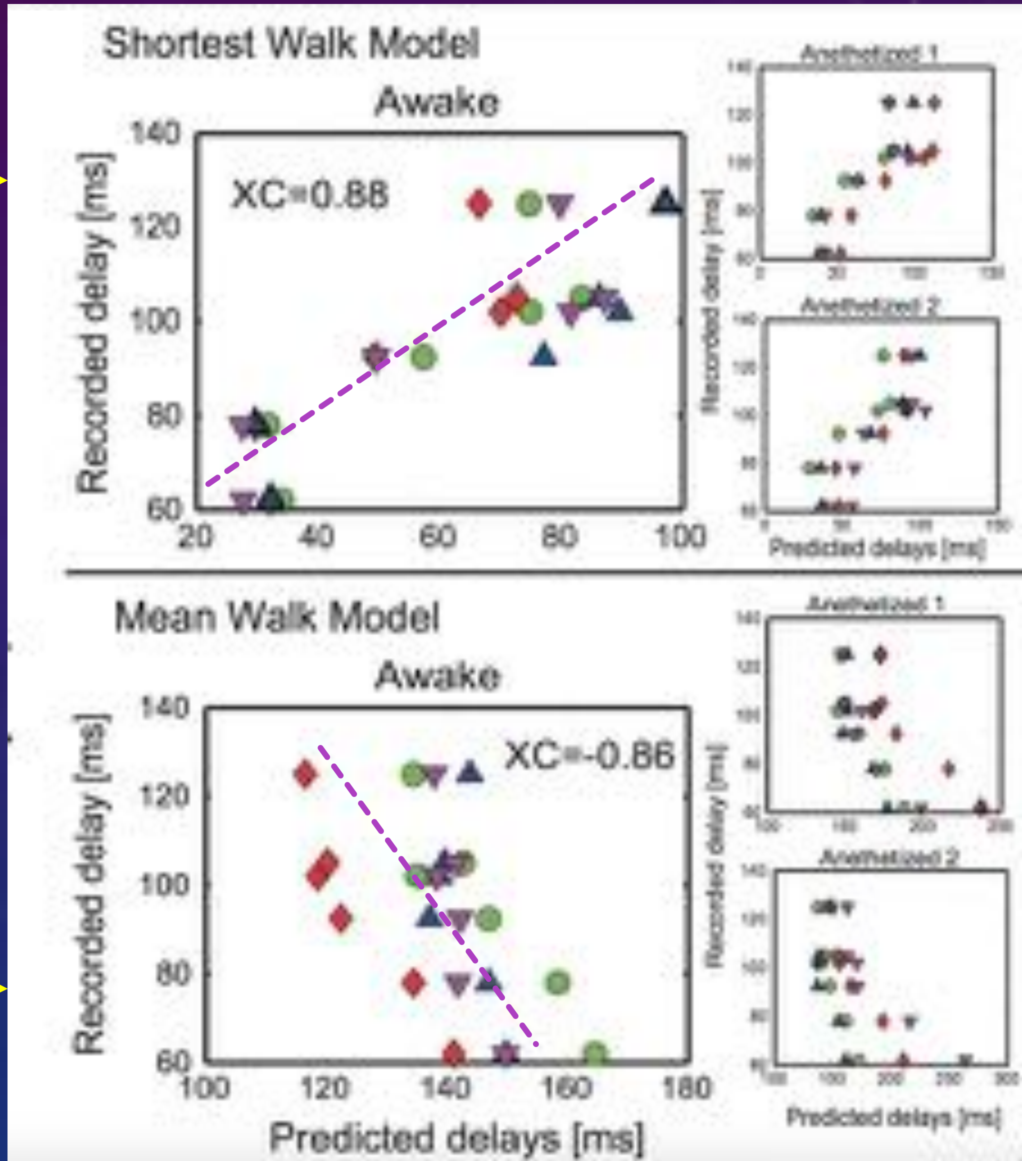




Shimono, Hatano (2016)

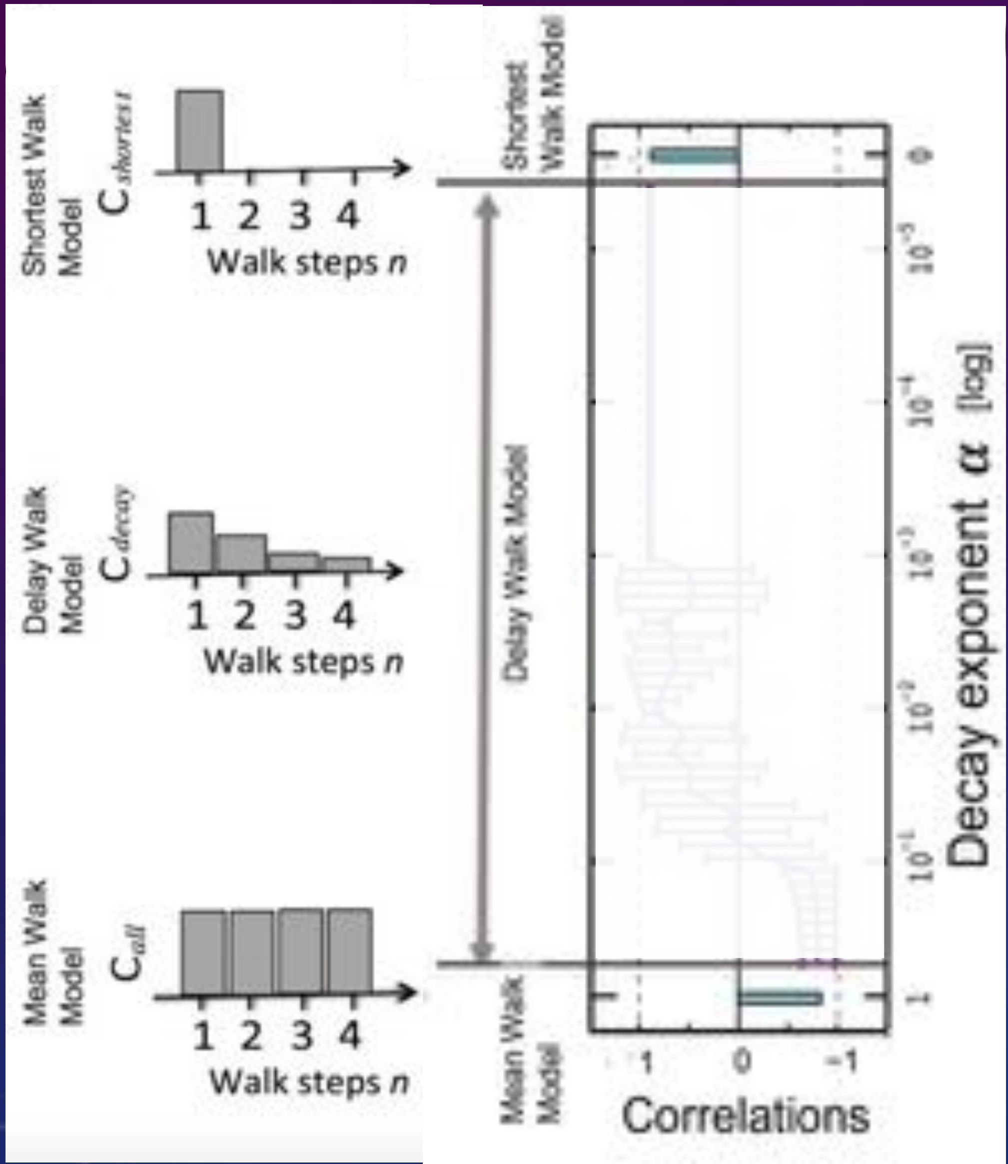
Contribution of indirect connections





Shimono, Hatano (2016)

Contribution of indirect connections

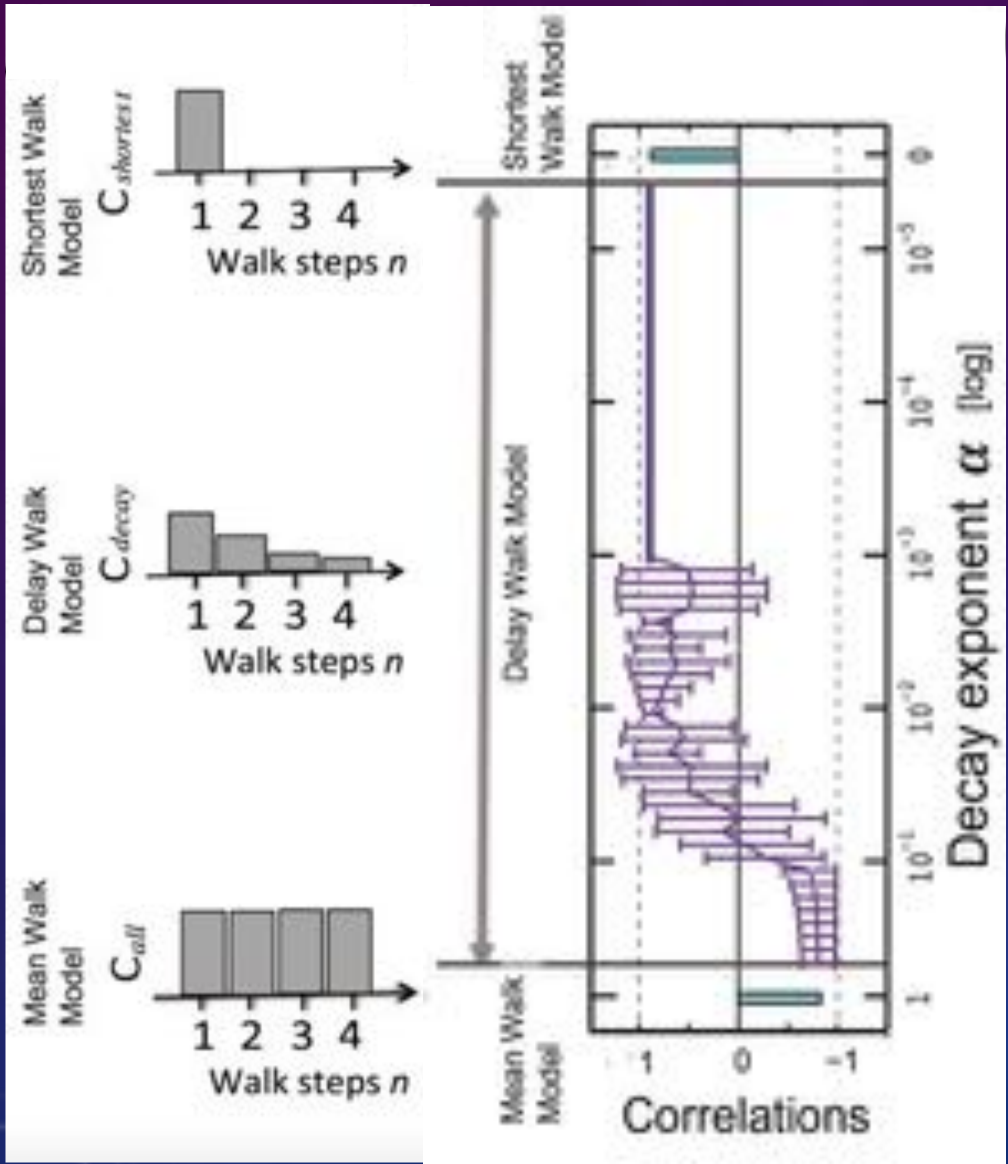


$C_{delay}(n)=\alpha^n$

(n : walk steps)

Shimono, Hatano (2016)

Contribution of indirect connections



$$C_{delay}(n)=\alpha^{n}$$

(n : walk steps)

Shimono, Hatano (2016)

Communicability G score

(Communicability)=(Weight) × (Walk length)

$$G = \sum_{n=0}^{\infty} c_n A^n = \sum_{n=0}^{\infty} (\alpha A)^n \qquad (c_n = \alpha^n)$$

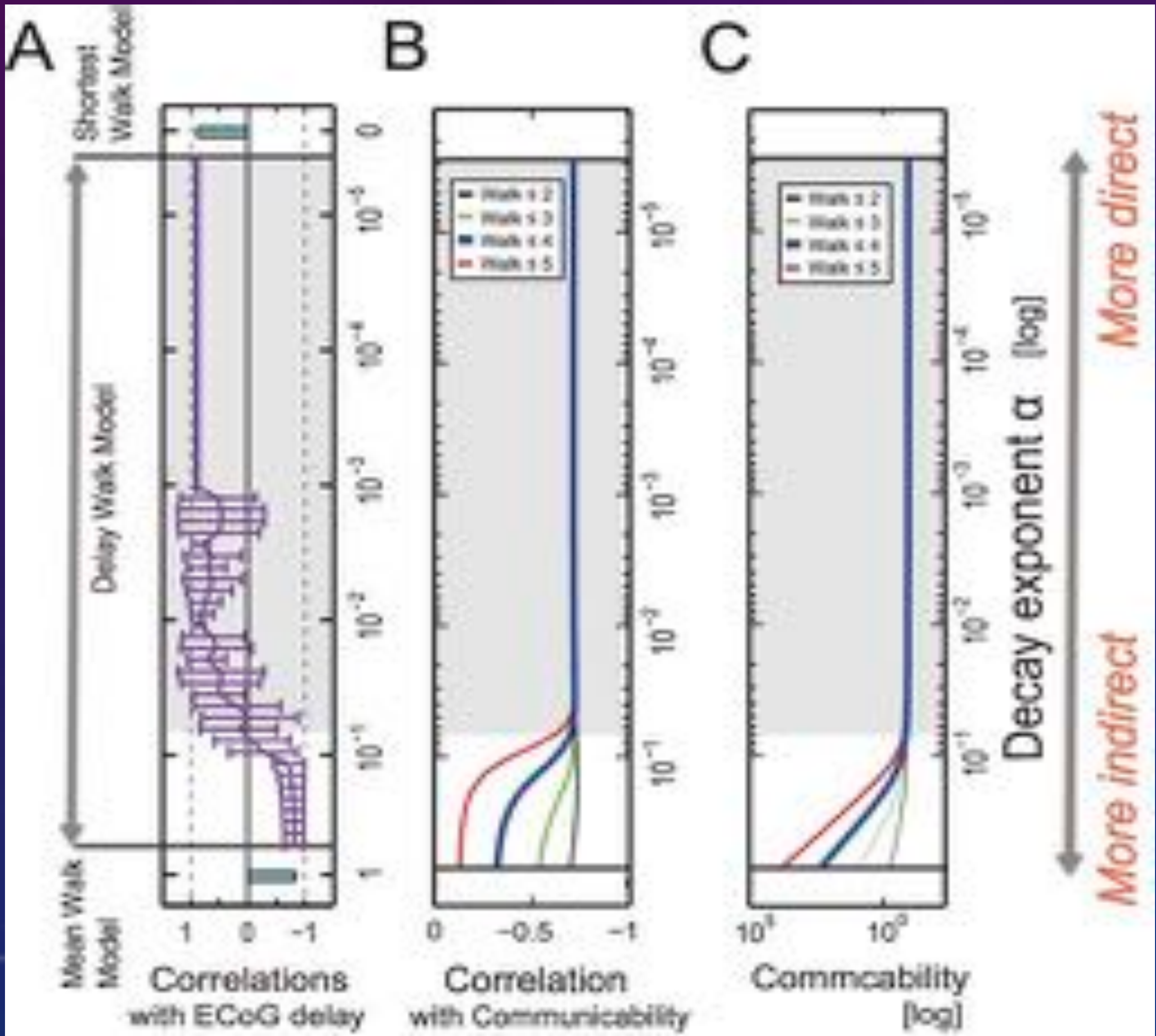
$$= \frac{1}{1 - \alpha A}$$

$$e.g.)\ A^3 = \sum_{k.l} A_{ik} A_{kl} A_{lj}$$

Communicability can systematically quantify how longer walks contribute to the spread of information in network systems.

Estrada, Hatano, (2008), Estrada, Hatano, Benzi (2012)

Communicability and latency



The contribution of indirect connections is …

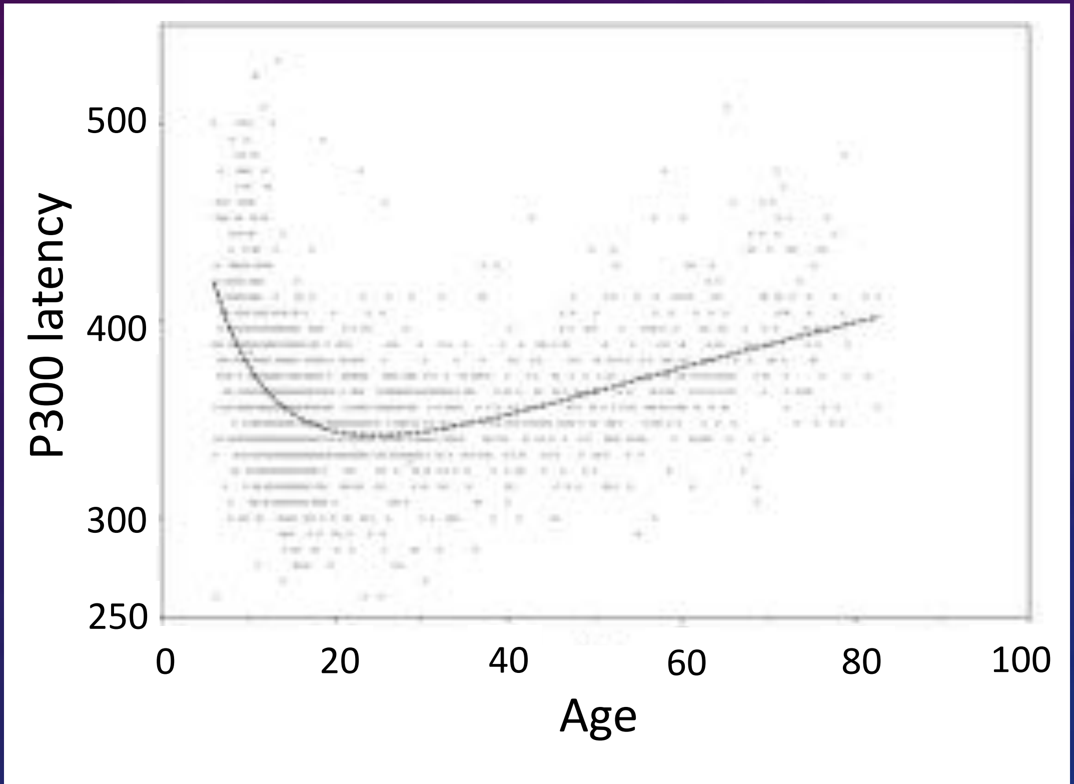
up to 5%.

… small?

Shimono, Hatano (2016)

Communicability and latency

e.g.) Age and P300



The contribution of indirect connections is …

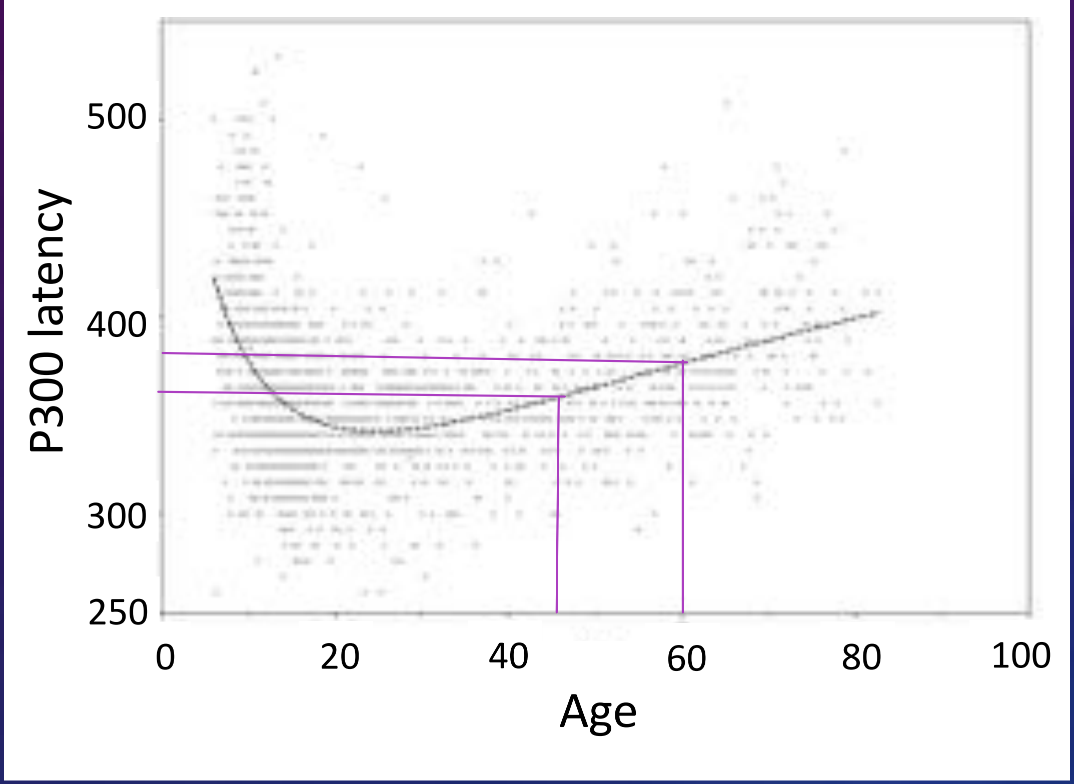
up to 5%.

… small?

Dinteren et al. (2014)

Communicability and latency

e.g.) Age and P300



The contribution of indirect connections is …

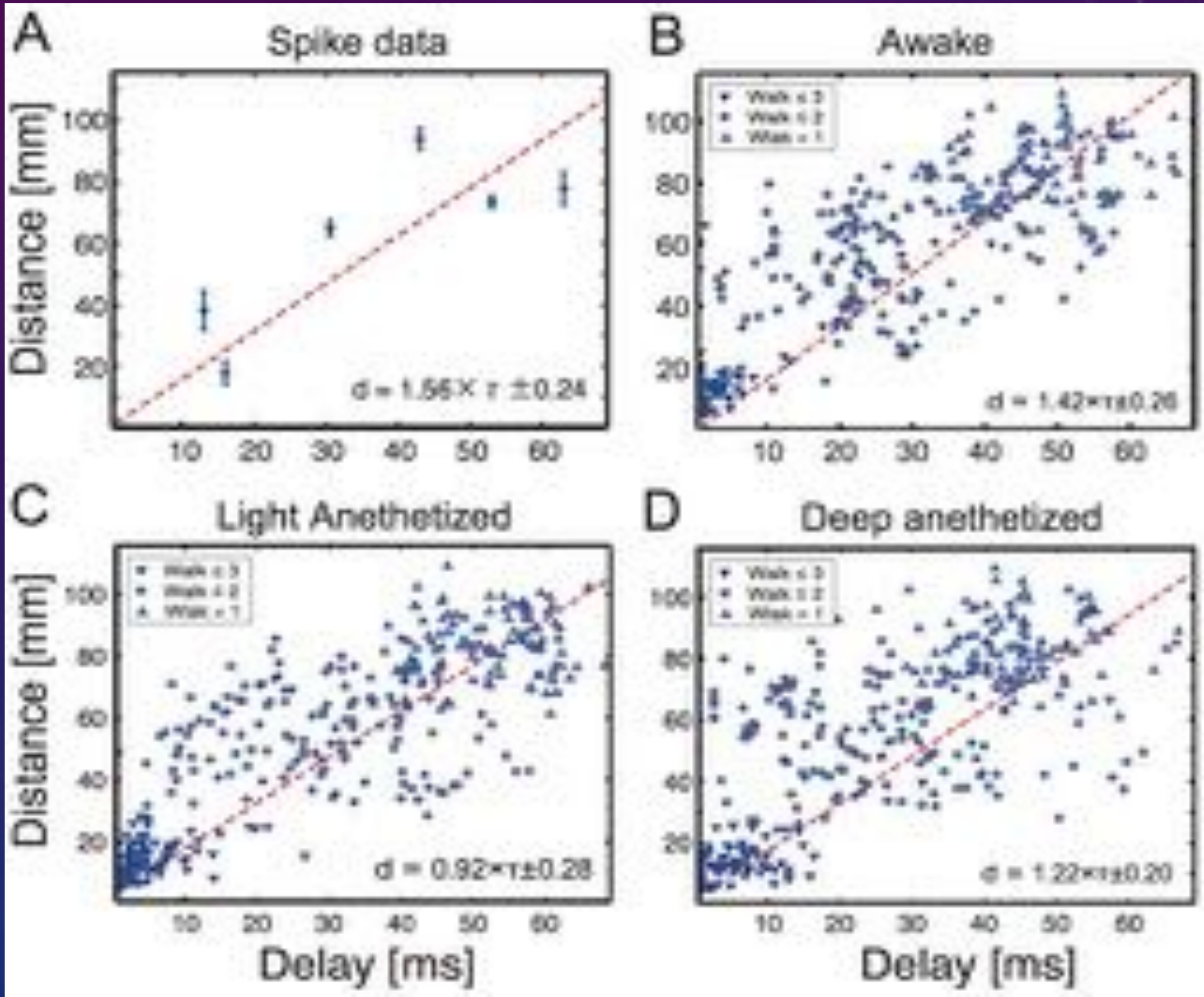
up to 5%.

… small?

Is the gap between ages 45 and 60 small?

Dinteren et al. (2014)

The propagation speed



Shimono, Hatano (2016)

Optimal speed and Stochastic Resonance

- From a computational modeling study

Wilson-Cowan model.

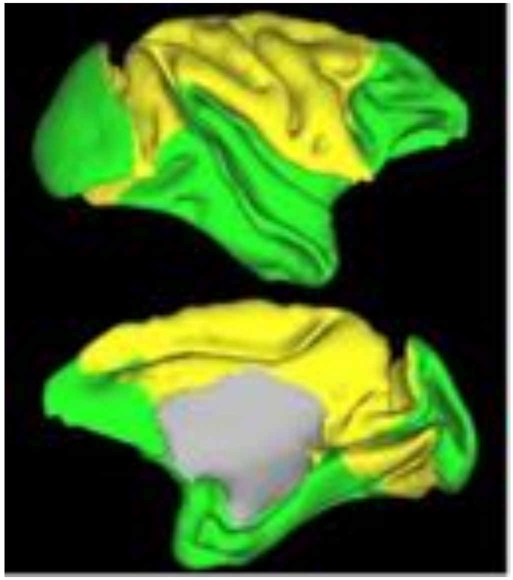
$$\tau \frac{\partial x_i(t)}{\partial t} = -x_i(t) + \phi(I_b + \sum_j \alpha C_{ij} x_j(t - T_{ji}) - y_i(t)) + \varepsilon_i(t)$$

α : global coupling strength

T_{ji} : Delay $\quad T_{ji} = d_{ji}/v$

Optimal working point P

Gap of synchronization levels



Girvan-Newman's method

→ Two modules

working point (*) is fixed between the 2 synchronization bumps

Transmission Velocity

Deco et al., (2009) PNAS

Optimal speed and Stochastic Resonance

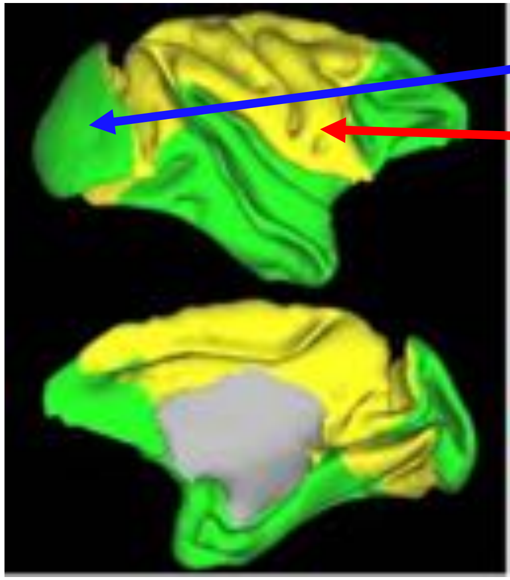
- From a computational modeling study

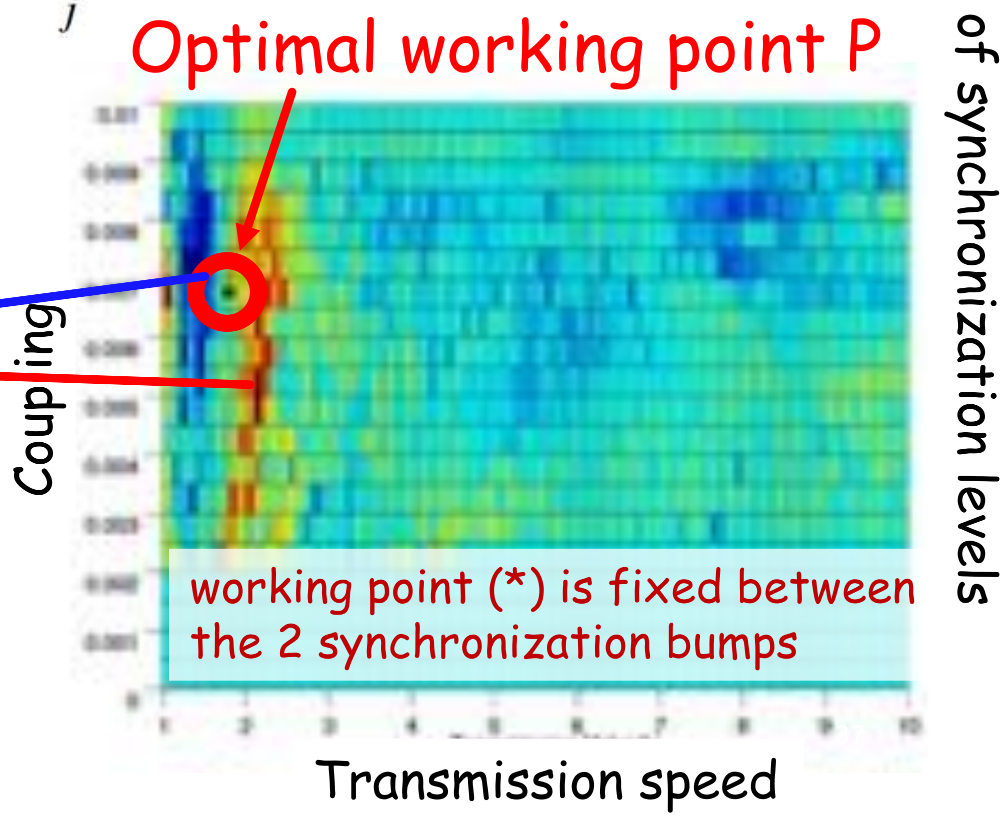
Wilson-Cowan model.

$$\tau \frac{\partial x_i(t)}{\partial t} = -x_i(t) + \phi\Big(I_b + \sum_j \alpha C_{ji} x_j(t - T_{ji}) - y_i(t)\Big) + \varepsilon_i(t)$$

α : global coupling strength

T_{ji} : Delay $\quad T_{ji} = d_{ji}/v$





Deco et al., (2009) PNAS

Contributions

1. ECoG can show consistent latencies with ones of neuronal spikes.
2. Spontaneous activity can also predict latencies of neuronal spikes.
   - Then, structural constraint is essential!!
3. Contributions of indirect connections are allowed up to 5%.
4. Communicability explains the percentage.
5. Transmission speed in the macro-connectome is 1.0~1.5m/s.
   - This is the optimal speed predicted by a past computational model study by Deco et al.

Shimono, Hatano (2016)


Article | OPEN

Efficient communication dynamics on macro-connectome, and the propagation speed

Masanori Shimono & Naomichi Hatano

Scientific Reports 8, Article number: 2510 (2018)
doi:10.1038/s41598-018-20591-y
Download Citation
Network models Network topology
Neuroscience

Received: 31 May 2017
Accepted: 22 January 2018
Published: 06 February 2018
Author Correction: 03 May 2018
Correction 03 May 2018

END