“When” on Macro-Connectome and Communicability

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How “When” of Neurodynamics is determined?
“When” of Neurodynamics

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

| 50–60 | 100 | 130–140 | 160 | 200–210 |

- M100
- M170

10^{-8}

0

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

Succeeded

45 132 296 384 [ms]

Comparisons with anatomical networks are necessary!!

"When" of Neurodynamics

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

![M100, M170](50-60, 100, 130-140, 160, 200-210)

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

![Succeeded](45, 132, 296, 384 [ms])

Many paths should exist!!

Liu, et al. (2002)

Chapman, Bragdon (1964), Shimono, et al. (2011)
Various brain-recording technologies

1. MRI
2. Dura
3. Arachnoid
4. Scalp
5. Skin
6. Space

MEG

EEG
Various brain-recording technologies

MEG
EEG
ECoG

MRI

Space
Skin
Scalp
Dura
Arachnoid

5cm
1cm
3cm
3cm
3cm
Various brain-recording technologies

Shimono, Hatano (2016)
Various brain-recording technologies

Resolution
- ECoG: Region ~1 cm
- LFP: ~1 mm
- S/MUA: Neuron ~1 µm
### Various brain-recording technologies

<table>
<thead>
<tr>
<th>Technology</th>
<th>Resolution</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECoG</td>
<td>Region: ~1 cm</td>
<td>Brain wide</td>
</tr>
<tr>
<td>LFP</td>
<td>~1 mm</td>
<td></td>
</tr>
<tr>
<td>S/MUA</td>
<td>Neuron: ~1 µm</td>
<td>Local</td>
</tr>
</tbody>
</table>
Various brain-recording technologies

Nagasaka et al. (2011)
Various brain-recording technologies

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

Shimono, Hatano (2016)
Shimono, Hatano (2016)

Evoked response & Spontaneous activity

- **Evoked response**
  - ECoG
  - Neuronal Spikes

- **Spontaneous activity**
  - Blind-fold condition
Evoked response & Spontaneous activity

ECoG

Evoked response

Spontaneous activity

Neuronal Spikes

Blind-fold condition

Shimono, Hatano (2016)
ECoG (Evoked) vs. Spikes (Evoked)

ECoG can predict neuronal spike delays within evoked conditions.
Evoked response & Spontaneous activity

Evoked response

Spontaneous activity

ECoG

Neuronal Spikes

Blind-fold condition

Blind-fold condition

Shimono, Hatano (2016)
ECoG (Spontaneous) vs. Spikes (Evoked)

Structural constraint Trace Injection data

ECoG (Spontaneous) vs. Spikes (Evoked)

$\tau(path \ index)(walk \ step)$
ECoG (Spontaneous) vs. Spikes (Evoked)

A first Walk step:

$\tau_{11}$
On one path:

\[ \tau_{11} + \tau_{12} + \tau_{13} + \tau_{14} = \tau_1 \]
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...
ECoG (Spontaneous) vs. Spikes (Evoked)

And...
ECoG (Spontaneous) vs. Spikes (Evoked)

We defined weight $C$ (decay index) depending on Walk steps.
ECoG (Spontaneous) vs. Spikes (Evoked)

The weighted averages represent delays of ECoG.
ECoG (Spontaneous) vs. Spikes (Evoked)

Finally, it was compared with as Correlations.
Contribution of indirect connections
Contribution of indirect connections

Shimono, Hatano (2016)
Contribution of indirect connections

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

($n$: walk steps)

Shimono, Hatano (2016)
Contribution of indirect connections

\[ C_{\text{delay}}(n) = \alpha^n \]

\( n \) : walk steps

Shimono, Hatano (2016)
Communicability can systematically quantify how longer walks contribute to the spread of information in network systems.
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.

\[
\tau \frac{dx_i(t)}{dt} = -x_i(t) + \phi(I_b + \sum \alpha C_{ji} y_j(t - T_{ji}) - y_i(t)) + \varepsilon_i(t)
\]

- \( \alpha \): global coupling strength
- \( T_{ji} \): Delay \( T_{ji} = d_{ji}/v \)

Girvan-Newman’s method

→ Two modules
From a computational modeling study

Wilson-Cowan model.

\[
\tau \frac{dx_i(t)}{dt} = -x_i(t) + \phi(I_b + \sum_j \alpha C_{ji} x_j(t - T_{ji}) - y_i(t)) + \varepsilon_i(t)
\]

- \(\alpha\): global coupling strength
- \(T_{ji}\): Delay \(T_{ji} = d_{ji}/v\)

Optimal working point \(P\)

working point (*) is fixed between the 2 synchronization bumps
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.\textsuperscript{38}
QUESTIONS?

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

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