Self-generated off-line memory reprocessing in a hierarchical recurrent neural network

Boosting recognition performance in absence of external stimuli

Jenia Jitsev

Max-Planck-Institute for Neurological Research, Cologne, Germany
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Memory network in the visual cortex

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Unsupervised learning of compositional object identity

Jitsev and von der Malsburg, 2009; Jitsev, 2010
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Network activity dynamics and competitive learning

Ongoing rhythms

| Cycle! |

T = 25 ms
Self-generated off-line memory reprocessing in a hierarchical recurrent neural network

Excitability regulation and memory trace formation

\[ \frac{d\theta}{dt} = \tau_{\theta}^{-1}(p_{\text{aim}} - \langle p \rangle), \]

Adaptive excitability

\[ \langle p \rangle = \frac{1}{T} \int_{t}^{t+T} p(t)dt, \]

Average activity in a cycle

\[ p_{\text{aim}} = \frac{1}{n} \]

Target activity

Intrinsic plasticity

Bottom-Up

Gabor Filter

Top-Down

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Max-Planck-Institute for neurological research

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Fully recurrent and purely feed-forward configuration

[Diagram of a hierarchical recurrent neural network with labeled components: Vocabulary layer, Lateral, Identity layer, Bottom-Up, Gabor Filter, Top-Down arrows.]


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Stimulus induced and self-generated activity

“Wake”, on-line (coupled to external input)

“Sleep / rest”, off-line (decoupled from external input)

Jitsev and von der Malsburg, 2010; Jitsev, 2010
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Generalization boost after the off-line regime

Identity error before and after "sleep"

Improving recognition function via off-line reprocessing

- The positive effect does **not** require synapse-specific plasticity
- The effect is stronger on the novel views not presented before
  → Off-line reprocessing boosts the ability to generalize

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Intrinsic excitability regulation in the "sleep" state

Vocabulary layer

Identity layer

Excitability regularized

Manual regularization

Condition
Regulated
Standard

Before Regularization

After Regularization

>30% !

Identify error rate

Face views

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Excitability equalization causes the positive effect

Positive effect does not depend on direction of regulation
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Off-line boost favors the fully recurrent configuration

Identity error after "sleep"

Identity Layer

<table>
<thead>
<tr>
<th>Face views</th>
<th>Error rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original</td>
<td>0</td>
</tr>
<tr>
<td>Duplicate</td>
<td>0.05</td>
</tr>
<tr>
<td>Sad</td>
<td>0.15</td>
</tr>
<tr>
<td>Smile</td>
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</tr>
<tr>
<td>Sad (Dupl.)</td>
<td>0.35</td>
</tr>
<tr>
<td>Smile (Dupl.)</td>
<td>0.45</td>
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</tbody>
</table>

Vocabulary Layer

Configuration
- Fully recurrent
- Purely feed-forward

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>25%! for Purely Feed-Forward configuration
Self-generated off-line memory reprocessing in a hierarchical recurrent neural network

Off-line boost favors the fully recurrent configuration

Identity error before "sleep"

Identity Layer

Vocabulary Layer

Configuration

- Fully recurrent
- Purely feed-forward
Self-generated off-line memory reprocessing in a hierarchical recurrent neural network

Off-line boost favors the fully recurrent configuration

Identity error after “sleep”

Identity Layer

Vocabulary Layer

![Graph showing error rates for different face views and configurations.]

Configuration
- Fully recurrent
- Purely feed-forward

>25%!
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Résumé

Improving recurrent neuronal network via off-line reprocessing

- Self-generated reprocessing in absence of external stimuli
- Strong boost in recognition performance after the off-line regime for the data not shown before
- The positive effect entirely mediated by synapse-unspecific excitability regulation
- Off-line boost favors fully recurrent architecture over purely feed-forward one

Jenia Jitsev
Max-Planck-Institute for neurological research

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Clinical Research Unit 219

Yasuomi D. Sato
Kyushu Institute of Technology (KYUTECH, Japan)

Christoph von der Malsburg

Wolf Singer Jochen Triesch Thomas Bunwick

Jörg Lücke Urs Bergmann Jörg Bornschein Christian Keck

Nikolai Axmacher
University Bonn, Clinics for Epileptology, Cortical Oscillations Group Bonn, Germany
Thanks for your Attention