Cooperative Synchronized Assemblies and Orientation Discrimination

Jason M. Samonds¹, John D. Allison², Heather A. Brown¹, A.B. Bonds¹,²

Vanderbilt University, Nashville TN, USA 37235
¹Department of Biomedical Engineering
²Department of Electrical Engineering and Computer Science
Cooperation Between Area 17 Neuron Pairs Enhances Fine Discrimination of Orientation


**2.0 ± 4.4%**

**57.6 ± 31.9%**

Cooperation for fine, but not gross, differences in orientation

35.5 ± 16.9% narrower **dependency** tuning allows finer discrimination of orientation than **rate** tuning

Samonds et al., VSS 2003 (jason.m.samonds@vanderbilt.edu)
Synchronized Assemblies

5 msec

Posterior - Anterior

Medial-Lateral

area centralis Area 17

1 mm

~100 repetitions 10-deg increments, 180 degrees
~500 repetitions 2-deg increments, 30 degrees

Samonds et al., VSS 2003 (jason.m.samonds@vanderbilt.edu)
Stimulus

Response

Bin Width

Letters

Types

Stimulus Repetition

Time

Neuron 1

Neuron 2

Calculating the "distance" between Type 1 and Type 2

Samonds et al., VSS 2003 (jason.m.samonds@vanderbilt.edu)
What is "distance"?

- One-half Resistor Average Kullback-Liebler Distance (KL distance) (Johnson et al., 2001)
- From the point of view of an optimal classifier (e.g., the lower limit of error based on classification theory when distinguishing responses)

\[
\text{misclassification} \propto 2^{-\text{distance}}
\]

- Probabilistic description of responses
  - Conditional on discharge history (D previous bins)
  - Estimations require more data with more cells and more history:

\[
D \leq \frac{\log(M + 1)}{\log(2^N + 1)} \quad M \text{ stimulus repetitions} \quad N \text{ neurons}
\]

Samonds et al., VSS 2003 (jason.m.samonds@vanderbilt.edu)
Type Analysis: Neural Dependence

Probability of Letter (observed)

<table>
<thead>
<tr>
<th>Type</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type 1</td>
<td>0.55</td>
<td>0.20</td>
<td>0.16</td>
<td>0.09</td>
</tr>
</tbody>
</table>

Probability of Letter (forced-independent)

<table>
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<tr>
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<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type 2</td>
<td>0.53</td>
<td>0.22</td>
<td>0.18</td>
<td>0.07</td>
</tr>
</tbody>
</table>

Dependency = “distance” between Type 1 and Type 2

If Cell 1 & 2 are independent, 
P(both) = P(cell 1) * P(cell 2)

Probability of Neuron Firing

- P(neuron 1) = 0.20 + 0.09 = 0.29
- P(neuron 2) = 0.16 + 0.09 = 0.25
- P(not neuron 1) = 0.55 + 0.16 = 0.71
- P(not neuron 2) = 0.55 + 0.20 = 0.75

Independent Letter Probabilities

- P(0) = (0.71)(0.75) = 0.53 (not neuron 1 and 2)
- P(1) = (0.29)(0.75) = 0.22 (neuron 1 and not 2)
- P(2) = (0.25)(0.71) = 0.18 (neuron 2 and not 1)
- P(3) = (0.29)(0.25) = 0.07 (both neuron 1 and 2)

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Type Analysis: Synergy

Ensemble Distance

<table>
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<th>Letter</th>
<th>0</th>
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<th>2</th>
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Independent Distance

<table>
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<tr>
<th>Letter</th>
<th>0</th>
<th>1</th>
</tr>
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</table>

\[
\text{Synergy} = \frac{d_{\text{ensemble}} - d_{\text{independent}}}{d_{\text{independent}}} \times (100\%)
\]

What percentage does the joint firing (e.g., letter 3) contribute to distance?

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Dependency vs. Assembly size

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Cooperation vs. Assembly Size

\[ R^2 = 0.78 \]
\[ R^2 = 0.26 \]
\[ R^2 = 0.87 \]
\[ R^2 = 0.37 \]

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Substrate for hyperacuity?

- Population code is needed
- Noise removal (e.g., averaging)
- Cooperative enhancement

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Conclusions

- Dependencies can enhance rather than hinder response discrimination.
- The cooperation is more apparent when testing the limits of single cell discrimination.
- The cooperation is more apparent as we examine more cells simultaneously.
- Cooperation arises from connectivity and possibly stimulus induced dependencies.
- Results suggest orientation-selective changes in synchrony (~5 ms) among small assemblies can improve the fidelity of single cell representations of orientation.
Acknowledgements

For very helpful comments and discussion

- Don Johnson
- Jonathan Victor
- George Gerstein
- Jeff Keating
- Fred Rieke
- Peter Dayan
- Bill Newsome
- Gerald Westheimer
- Cristoph von der Malsburg
- Reinhard Eckhorn
- Wolf Singer
- Hugh Wilson

Supported by National Eye Institute
Grant RO1EY-03778-20

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