TTX and BCM

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Outline

1. BCM and Presynaptic Activity
   - Experimental Results
   - BCM Theory

2. Assumptions about Activity in LGN
   - The Usual Suspects

3. Simulations
   - Normal Development
   - Deprivation
   - Conclusions
Normal Rearing (NR)
Frenkel and Bear, 2004

- contralateral bias magnitude $\sim 2.5$
- VEP includes responses from *populations* of cells

**VEP amplitude**
(normalized to day 0 ipsi)

<table>
<thead>
<tr>
<th></th>
<th>Day 0</th>
<th>Day 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>VEP</td>
<td>2.2</td>
<td>2.8</td>
</tr>
<tr>
<td>$n$</td>
<td>7</td>
<td>7</td>
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Monocular Suture (MS) and Inactivation (MI)
Frenkel and Bear, 2004

**MS**
- contra responses decrease

**MI**
- contra responses constant
- ipsi responses increase faster than MS
**Visual Cortex Receptive Field Plasticity**
Blais et al., 1999

**BCM Synaptic Modification**

\[
\frac{dw_i}{dt} = \phi(y, \theta_M) x_i
\]

\[
\theta_M \sim E[y^2]
\]

**BCM Rule Predicts Deprivation Dynamics**

- Natural Images
- Requires Pre-synaptic Activity
- Model Architecture: Cat
Normal Rearing Simulations

C/I = 2.2
Monocular Suture (MS) and Inactivation (MI) Simulations

**MS**
- Contra responses decrease

**MI**
- Contra responses constant
- Ipsi responses increase faster than MS
Monocular Suture
Natural Input versus Noise

Normal Input
- Structure

Deprived
- Noise

structure is correlated: nearby inputs have similar activities
noise is uncorrelated: inputs have unrelated activities
Monocular Inactivation
Natural Input versus Low Noise

Normal Input
- Structure

Inactivated
- Noise

- noise has smaller variance than for lid suture
- noise is uncorrelated: inputs have unrelated activities
Notation

Equations

inputs: $\mathbf{x} = (x_1, x_2, \cdots)$

weights: $\mathbf{w} = (w_1, w_2, \cdots)$

output: $y = \sigma(x_1 \cdot w_1 + x_2 \cdot w_2 + \cdots) = \sigma(\mathbf{x} \cdot \mathbf{w})$
BCM and Deprivation

\[ \phi(y) \]

\[ \theta_M \]

\[ y \rightarrow \]

\[ w_{ic}, w_{io}: \text{closed/open eye synapses} \]

**Case 1: Activities Around Zero**

\[ \frac{d w_{ic}}{d t} = -\epsilon y_n_i \]
Case 1: Activities Around Zero

\[
\frac{dw_{ic}}{dt} = -\epsilon yn_i \\
= -\epsilon (w_{1o}s_1 + w_{2o}s_2 + \cdots + w_{1c}n_1 + w_{2c}n_2 + \cdots) n_i
\]
Case 1: Activities Around Zero

\[
\frac{dw_{ic}}{dt} = -\epsilon yn_i \\
= -\epsilon (w_{1o}s_1 + w_{2o}s_2 + \cdots + w_{1c}n_1 + w_{2c}n_2 + \cdots )n_i \\
\left\langle \frac{dw_{ic}}{dt} \right\rangle = -\epsilon w_{ic} \langle n_i^2 \rangle
\]
Case 2: Activities Around $\theta_M$

$$\frac{dw_{ic}}{dt} = +\epsilon y_i$$

$w_{ic}, w_{io}$: closed/open eye synapses
BCM and Deprivation

Case 2: Activities Around $\theta_M$

\[
\frac{dw_{ic}}{dt} = +\epsilon y_n_i
\]

\[
= +\epsilon( w_{1o}s_1 + w_{2o}s_2 + \cdots + w_{1c}n_1 + w_{2c}n_2 + \cdots )n_i
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$w_{ic}, w_{io}$: closed/open eye synapses
BCM and Deprivation

\[ \phi(y) \]

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**Case 2: Activities Around \( \theta_M \)**

\[
\frac{dw_{ic}}{dt} = +\epsilon yn_i \\
= +\epsilon (w_{1o}s_1 + w_{2o}s_2 + \cdots + w_{1c}n_1 + w_{2c}n_2 + \cdots) n_i \\
\langle \frac{dw_{ic}}{dt} \rangle = +\epsilon w_{ic} < n_i^2 >
\]
BCM and Deprivation

\[ \frac{dw_{ic}}{dt} = \begin{cases} 
- N_0 \times \epsilon w_{ic} < n_i^2 > 
+ N_\theta \times \epsilon w_{ic} < n_i^2 > 
\end{cases} \]

\( w_{ic}, w_{io} \): closed/open eye synapses
BCM and Deprivation

\[ \phi(y) \]

\[ y \]

\[ \theta_M \]

\[ w_{ic}, w_{io} : \text{closed/open eye synapses} \]

**Case 1 (0) and Case 2 ($\theta_M$)**

\[
\frac{dw_{ic}}{dt} = \underbrace{-N_0 \times \epsilon w_{ic} < n_i^2 >} + \underbrace{N_{\theta} \times \epsilon w_{ic} < n_i^2 >}
\]

\[ N_0 \gg N_{\theta} \text{ (selective)} \]
Monica’s Experiments

LGN activity for normal viewing, lid suture, and TTX are very similar. LGN activity with TTX is more correlated, and bursty, than LGN activity with lid suture.
Monica’s Experiments

- LGN activity for normal viewing, lid suture, and TTX are very similar
Monica’s Experiments

- LGN activity for normal viewing, lid suture, and TTX are very similar
- LGN activity with TTX is *more correlated*, and bursty, then LGN activity with lid suture
One Attempt

Assumption for LGN Activity during TTX

Instead of small variance, mean zero noise for TTX, assume small variance *positive mean* noise
One Attempt

Assumption for LGN Activity during TTX

Instead of small variance, mean zero noise for TTX, assume small variance positive mean noise

This makes the neighboring inputs more (perhaps too) correlated.
One Attempt

Assumption for LGN Activity during TTX

Instead of small variance, mean zero noise for TTX, assume small variance *positive mean* noise

This makes the neighboring inputs more (perhaps too) correlated.

What happens?
Normal Development (Cats)

Exploratory mode: use cat sims for speed
Monocular Suture (Cats)

Noise
- Mean 0.0
- Std 0.8
Monocular Inactivation (Cats)

Noise
- Mean 0.0
- Std 0.005

BCM and Presynaptic Activity

Assumptions about Activity in LGN

Simulations

[Graphs and data points]
Monocular Inactivation (Cats)

Noise
- Mean 0.5
- Std 0.005
Monocular Inactivation (Cats)

Sample Input Vector

-2
-1
0
1
2
3

Activity

Noise

Mean 0.5
Std 0.005
Monocular Suture (Cats)

Noise
- Mean 0.5
- Std 0.8
Monocular Suture (Cats)
Using non-zero mean noise...

- ...the TTX activities become very correlated
- ...the results for MS and MI are identical