### The cellular basis of receptive field plasticity in visual cortex, an integrative experimental and theoretical approach

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#### PROJECT SUMMARY

Synaptic plasticity is a likely basis for information storage by the neocortex. Understanding cortical plasticity requires coordinated investigation of both underlying cellular mechanisms and their system-level consequences in the same model system. However, establishing connections between the cellular and system levels of description is non-trivial. A major contribution of theoretical neuroscience is that it can link different levels of description, and in doing so can direct experiments to the questions of greatest relevance.

The objective of the current project is to generate a theoretical description of experience-dependent plasticity in the rodent visual system. The advantages of rodents are, first, that knowledge of the molecular mechanisms of synaptic plasticity is relatively mature and continues to be advanced with genetic and pharmacological experiments, and second, rodents show robust receptive field plasticity in visual cortex (VC) that can be easily and inexpensively monitored with chronic recording methods.

The project aims are threefold. First, the activity of inputs to rat visual cortex will be recorded in different viewing conditions that induce receptive field (RF) plasticity, and these data will be integrated into models of synaptic plasticity. Second, the dynamics of RF plasticity will be simulated using existing spike rate-based algorithms and compared with experimental observations. Third, the consequences of new biophysically plausible plasticity algorithms, based on spike timing and metaplasticity, will be analyzed and compared with experiments.

#### Modeling Deprivation in mouse

**Chronic VEP recordings**

<table>
<thead>
<tr>
<th>Condition</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lid Suture</td>
<td>No change</td>
</tr>
<tr>
<td>Show 2.6</td>
<td>Depression</td>
</tr>
</tbody>
</table>

#### Multi spike protocols

**Response to triplets: deterministic vs. stochastic**

<table>
<thead>
<tr>
<th>Protocol</th>
<th>Deterministic</th>
<th>Stochastic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-post-pre</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Post-pre-post</td>
<td>Depression</td>
<td></td>
</tr>
</tbody>
</table>

#### Calcium-dependent model for Synaptic Plasticity

(Hosh, 2002)

1. The Ca-control hypothesis:  
   - High Ca results in depression
   - Low Ca results in potentiation
2. The NMDA receptors are primary source of calcium
3. The back-propagating action potential (BAP) which has a slow tail contributes to Ca current flow

**Comparison of Ca and weight changes in deterministic and stochastic models**

<table>
<thead>
<tr>
<th>Model</th>
<th>Initial Weight</th>
<th>Weight Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deterministic</td>
<td>0.5</td>
<td>0.3</td>
</tr>
<tr>
<td>Stochastic</td>
<td>0.5</td>
<td>0.2</td>
</tr>
</tbody>
</table>

#### Recording of LGN activity in vivo (unfunded)

- Neurons recorded continuously for 48 hours before and after TTX injection
- Offline classification of LGN spike waveform (yellow) from multiunit activity
- Stability of identified LGN neurons across 48 hours as shown by blocking the recording into 4 consecutive epochs and overlaying the average waveforms
- Interspike interval distributions taken from this LGN neuron before and after the application of TTX into the contralateral eye during active exploration in the illuminated environment
- Surprisingly, there was no significant change in the mean firing pre-versus post TTX injection (4Hz), but there was a significant drift in firing pattern

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**Analysis of spike statistics and parameter dependence**

- 1. Probability of release
- 2. Synaptic facilitation
- 3. BAPP attenuation
- 30% BPAP Attenuation

**Multi spike protocols**

1. Stochastic presynaptic dynamics determine the outcome of post-pre-post protocols.
2. BPAP dynamics determine the outcome of post-pre-post protocols.
3. Spike statistics can be calculated and used to analyze the parameter dependence of multi-spike plasticity protocols.