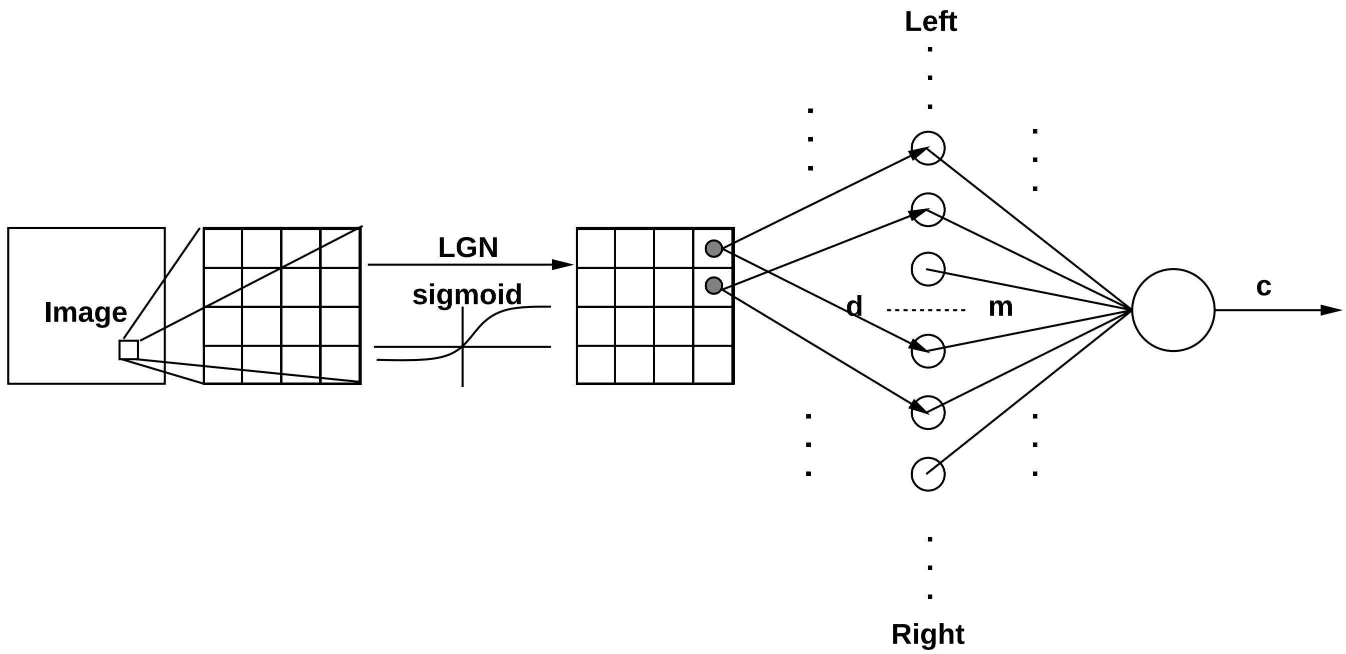
Single Cell BCM with Natural Scene Input

- define the problem, notation, and implementation
- measure of the "1/2" life of activity
- compare learning rules
- effect of non-linearities in cortical and LGN cells
- effect of changing the memory constant, τ, and the learning rate, η



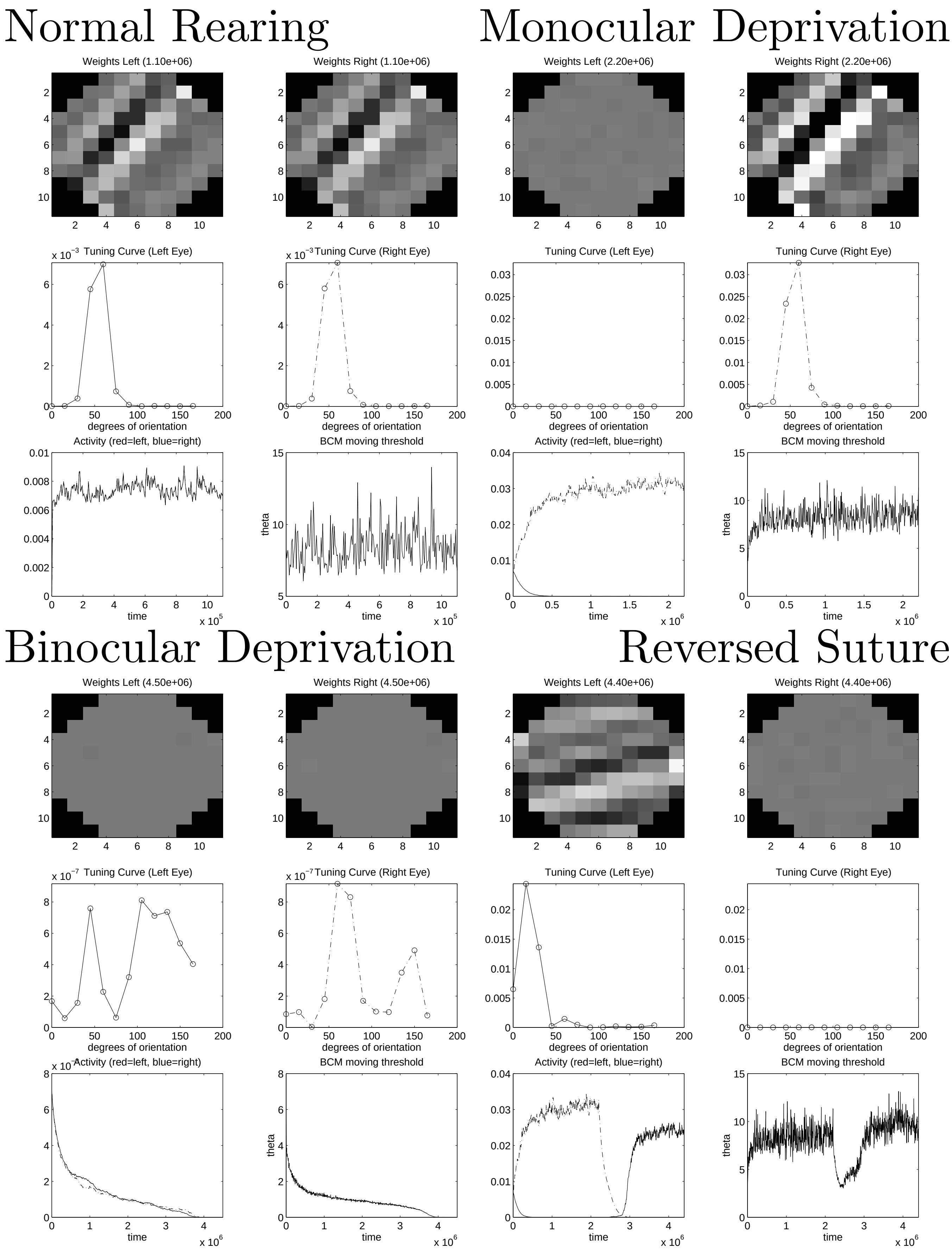
- image values before LGN sigmoid: $\approx [-5:5]$
- sigmoid defined:

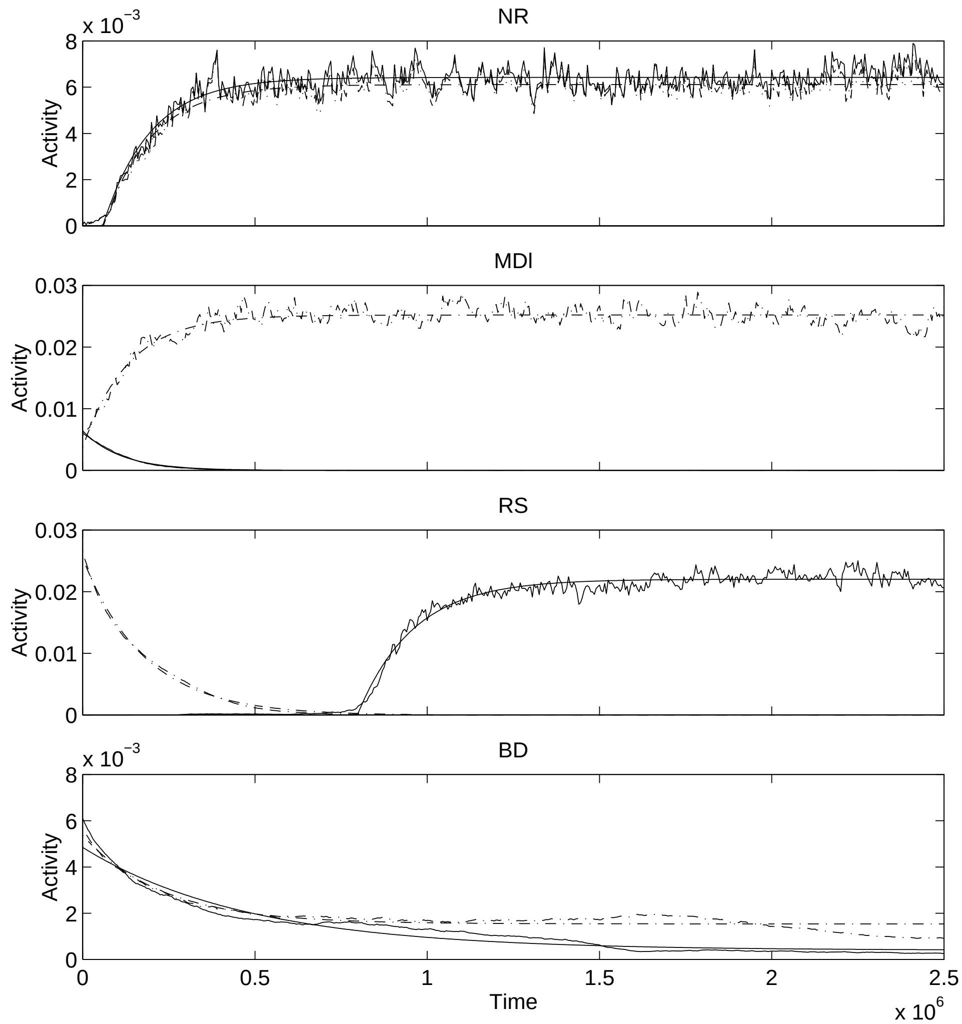
$$\sigma(x, v_1, v_2) \equiv \begin{cases} v_2\left(\frac{2}{1+\exp(-2x/v_2)} - 1\right) & \text{if } x > 0 \\ v_1\left(\frac{2}{1+\exp(-2x/v_1)} - 1\right) & \text{if } x < 0 \end{cases}$$

- LGN sigmoid: $\sigma(x, -2.0, 7.0)$
- cortical sigmoid: $\sigma(x, -1.0, 50.0)$
- $c = \sigma_{\text{cortical}}(\mathbf{m} \cdot \mathbf{d})$
- $\dot{\theta} = \frac{1}{\tau}(c^2 - \theta)$
- $\dot{\mathbf{m}} = \eta c(c - \theta)\mathbf{d}$ or $\dot{\mathbf{m}} = \eta c(c - \theta)\mathbf{d}/\theta$

Classical Rearing Experiments

- Normal Rearing (NR):
  - · start **unselective** (random weights)
  - · **both** eyes are presented with input
  - ∗ develop **orientation selectivity** in **both** eyes
- Monocular Deprivation (MD):
  - · start after NR, with both eyes selective
  - · **one** eye is closed (presented with uncorrelated input)
  - ∗ closed eye **loses selectivity** and drops to zero activity
  - ∗ open eye becomes **stronger** (occular dominance shift)
- Binocular Deprivation (BD):
  - · start after NR, with both eyes selective
  - · **both** eyes are closed
  - ∗ **no** OD shift, neuron remains **binocular**
  - ∗ closed eyes drop in activity, but **not** to zero
  - ∗ drop in activity is **slower** than MD
- Reversed Suture (RS):
  - · start after MD, with one eye selective
  - · the closed eye is now open, and the open eye is closed
  - ∗ newly open eye recovers activity **after** the newly closed eye loses activity
  - ∗ drop in activity is **slower** than MD

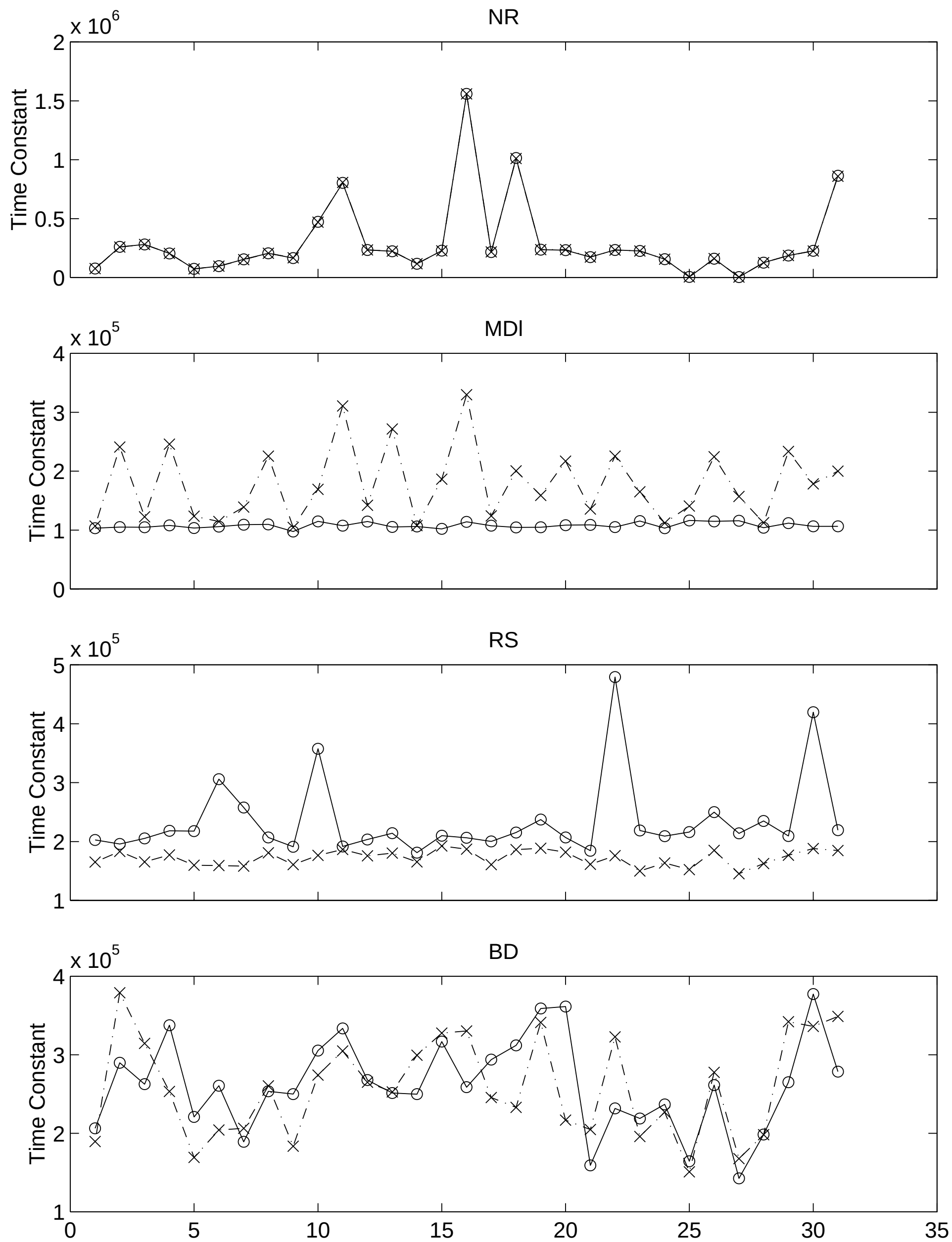

Normal Rearing
Monocular Deprivation
Binocular Deprivation
Reversed Suture
Weights Left (1.10e+06)
Weights Right (1.10e+06)
Weights Left (2.20e+06)
Weights Right (2.20e+06)
Weights Left (4.50e+06)
Weights Right (4.50e+06)
Weights Left (4.40e+06)
Weights Right (4.40e+06)
Tuning Curve (Left Eye)
Tuning Curve (Right Eye)
degrees of orientation
Activity (red=left, blue=right)
BCM moving threshold
theta
time



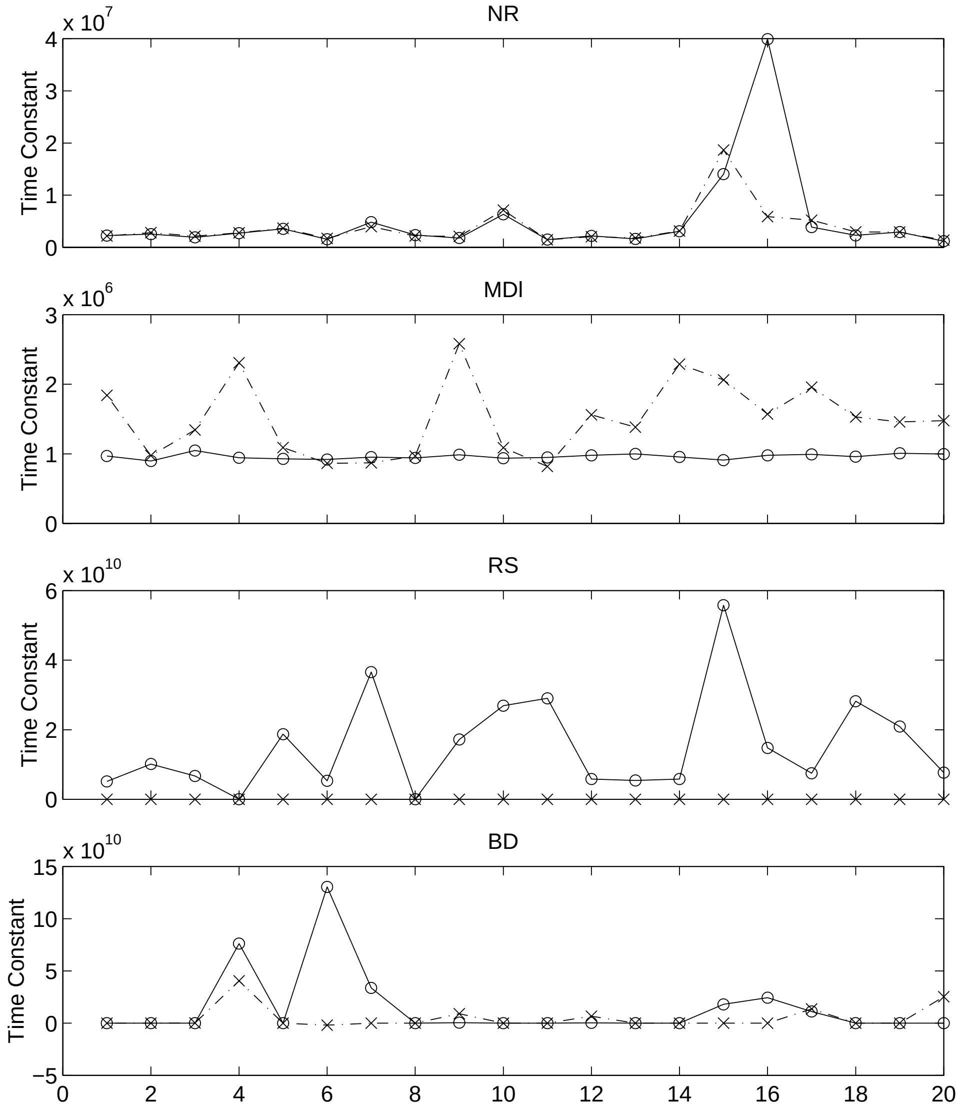
- fit to $y(t) = \Theta(t - t_0) \cdot (y_1 + y_0 e^{(t - t_0)/t_1})$
- $\Theta(t - t_0)$ defined:

$$\Theta(t - t_0) \equiv \begin{cases} 1 \text{ if } t > t_0 \\ 0 \text{ if } t < t_0 \end{cases}$$

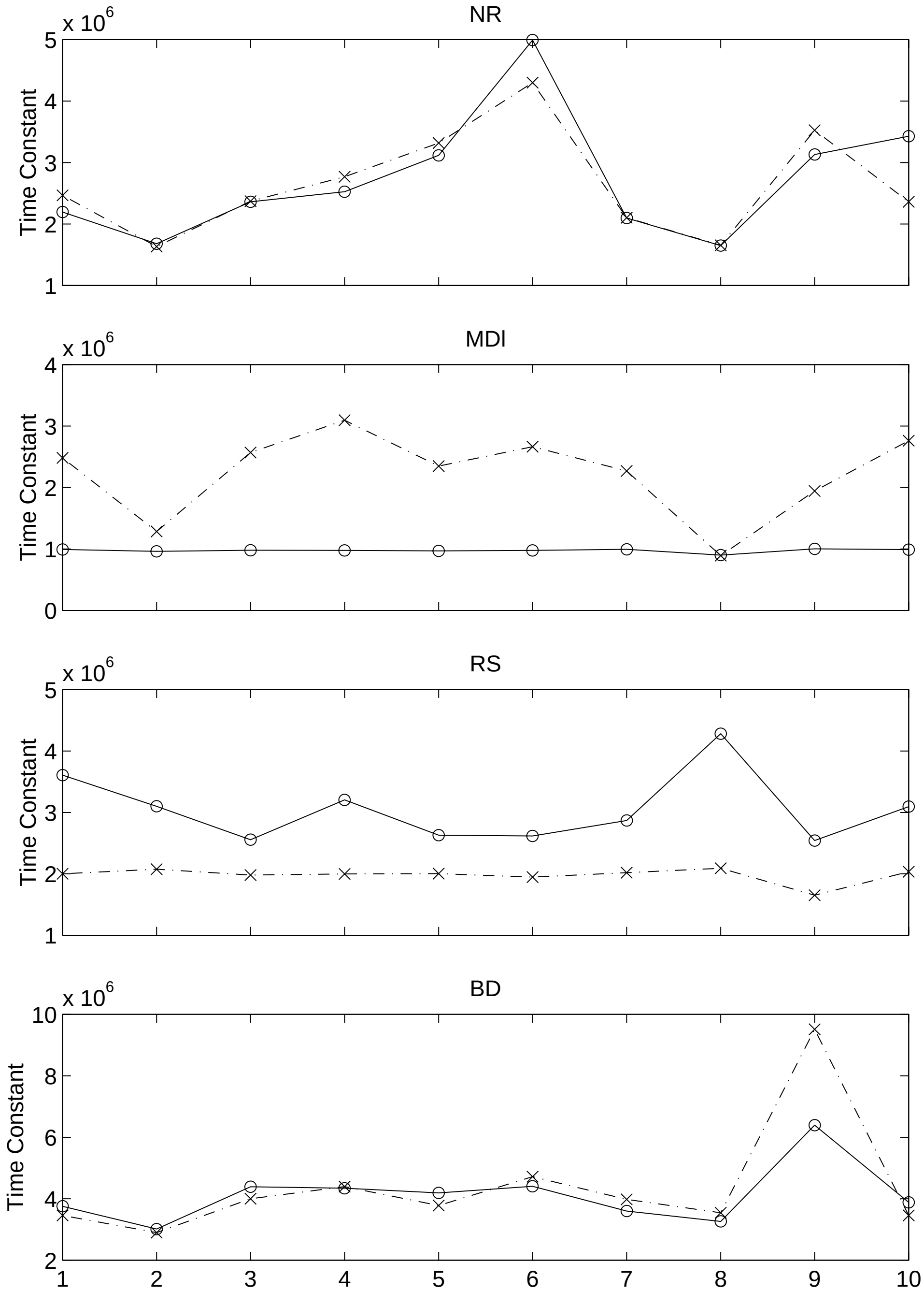
- $t_0 \equiv$ the time where the activity passes above $\frac{1}{30}$ of maximum. (threshold is arbitrary)



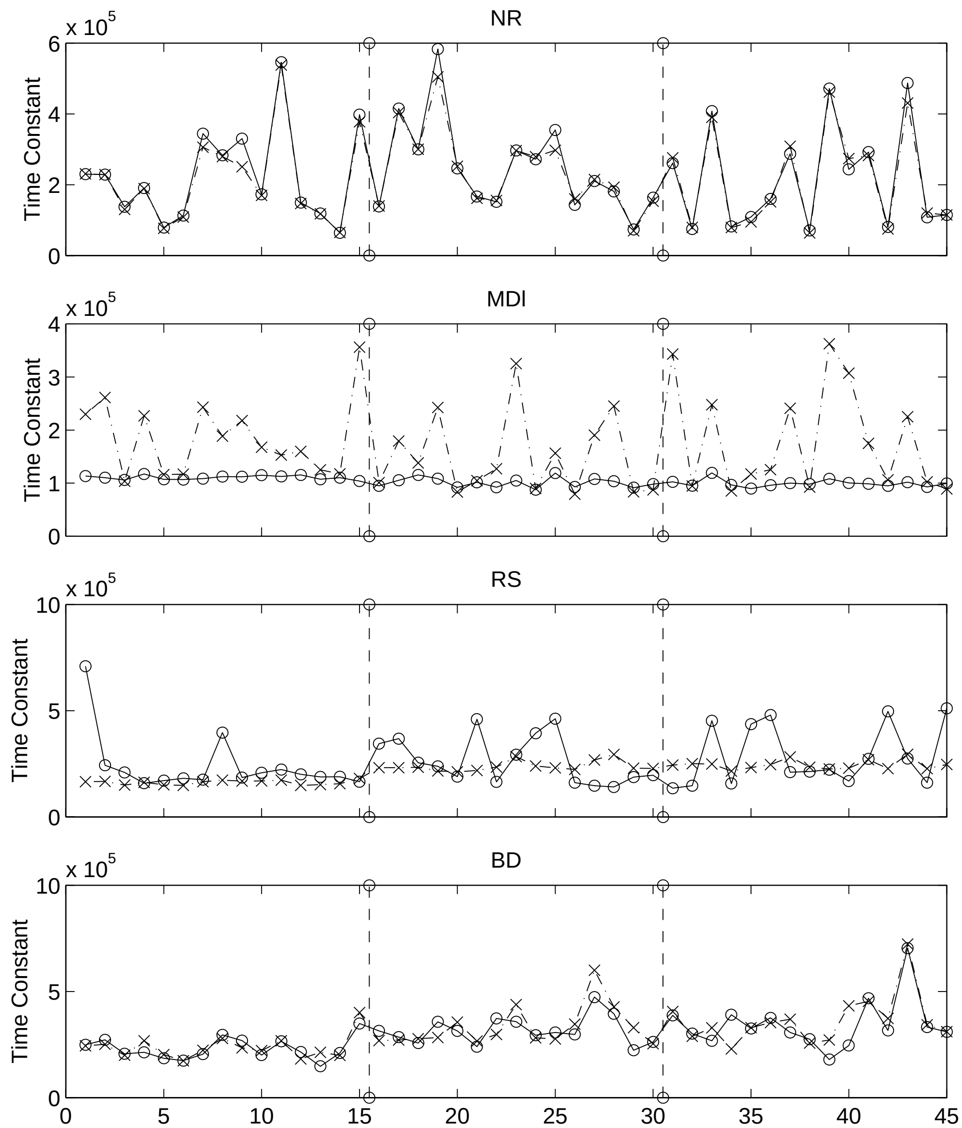
- $\tau = 1000$, $\eta = 5 \cdot 10^{-5}$, learning rule with $1/\theta$.
- Development times (t_1) in units of $1/\eta$.
  - · NR: 14.9 14.9
  - · MD (left closed): 5.4 8.9
  - · RS: 11.7 8.6
  - · BD: 13.1 12.9



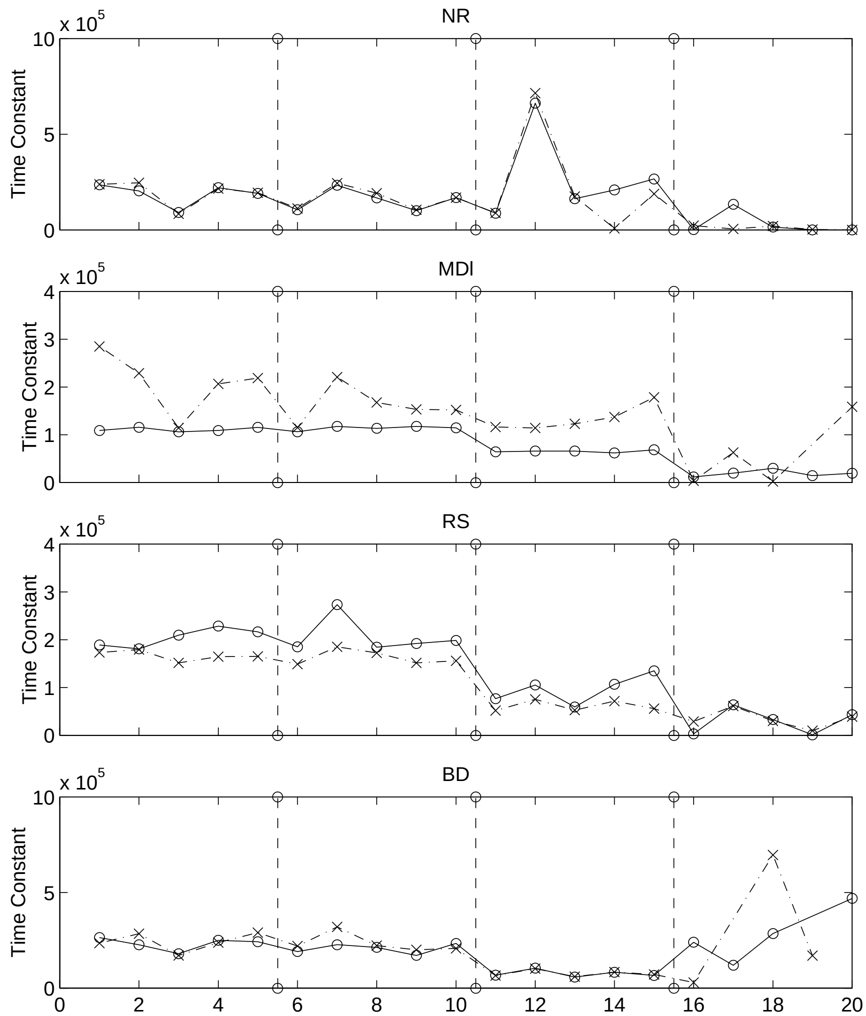
- $\tau = 2000$, $\eta = 5 \cdot 10^{-6}$, learning rule **without** $1/\theta$
- Development times (t_1) in units of $1/\eta$.
  - · NR: 1.5 1.5
  - · MD (left closed): 0.8 1.3
  - · RS: 2.7 2.1
  - · BD: 2.6 2.5



- $\tau = 2000$, $\eta = 5 \cdot 10^{-6}$, learning rule with $1/\theta$
- Development times (t_1) in units of $1/\eta$.
  - NR: 13.59 13.25
  - MD (left closed): 4.87 11.15
  - RS: 15.25 9.90
  - BD: 20.62 21.87



- The figure is broken up into three sections corresponding to
  - $\cdot\ \sigma_{\mathrm{LGN}}(x, -2, 2)$
  - $\cdot\ \sigma_{\mathrm{LGN}}(x, -2, 7)$
  - $\cdot\ \sigma_{\mathrm{LGN}}(x, -7, 7)$
- development times are **not** sensitive to changes in the LGN sigmoid



- The figure is broken up into four sections corresponding to
  - $\cdot\, \tau = 250$ and $\eta = 5 \cdot 10^{-5}$
  - $\cdot\, \tau = 500$ and $\eta = 5 \cdot 10^{-5}$
  - $\cdot\, \tau = 1000$ and $\eta = 1 \cdot 10^{-4}$
  - $\cdot\, \tau = 1000$ and $\eta = 5 \cdot 10^{-4}$
- if η is too large, then the neuron does not become selective
- the model is fairly robust to changes in the memory constant, τ

Conclusions

- have a quantitative measure of the development times for the neuron
- measure could be used to guess simulation run times
- high variance makes it more difficult to notice effects of parameters
- learning rule with $1/\theta$ more robust with parameters, but slower than the rule without the $1/\theta$
- neuron is robust over changes in LGN sigmoid, and in the memory constant
- neuron is sensitive to high learning rates