Adaptive Coding of Motion in Macaque Visual Cortex

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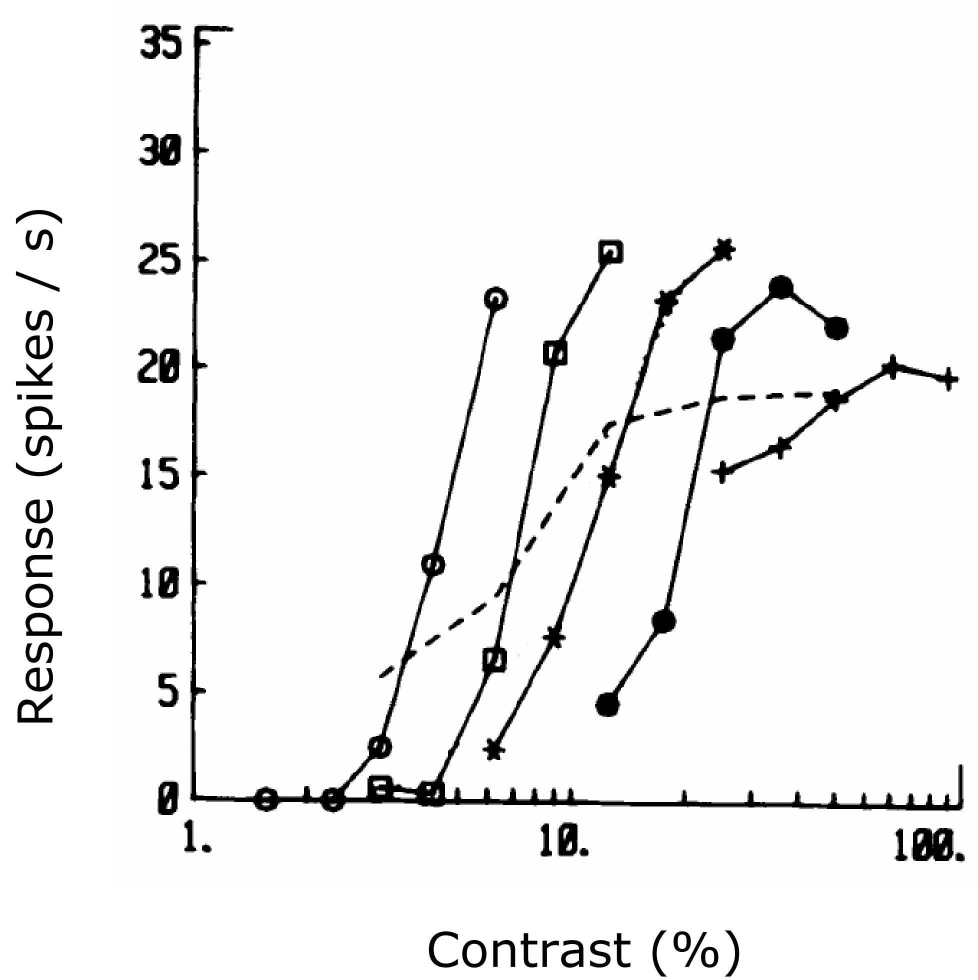
Adaptation in Sensory Systems - an Example: Cortical Contrast Gain Control

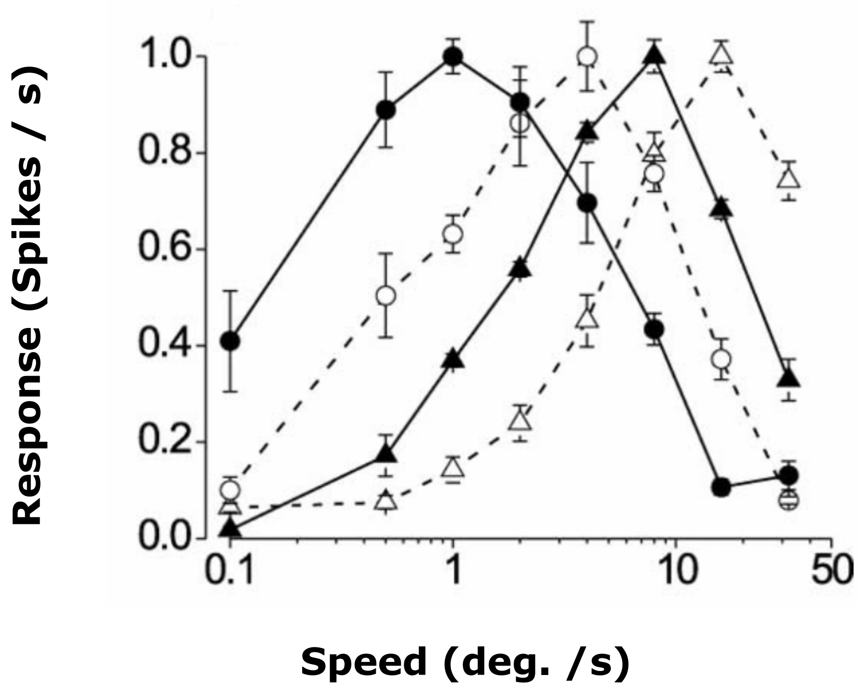


Ohzawa et al., 1985

[Recording from: V1 simple cell, anaesthetized cat]

Motion Coding in Visual Cortex

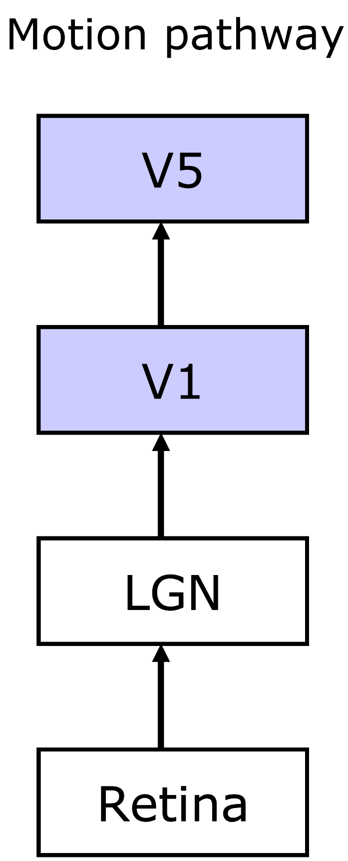
"Labeled-line" models based fixed tuning curves

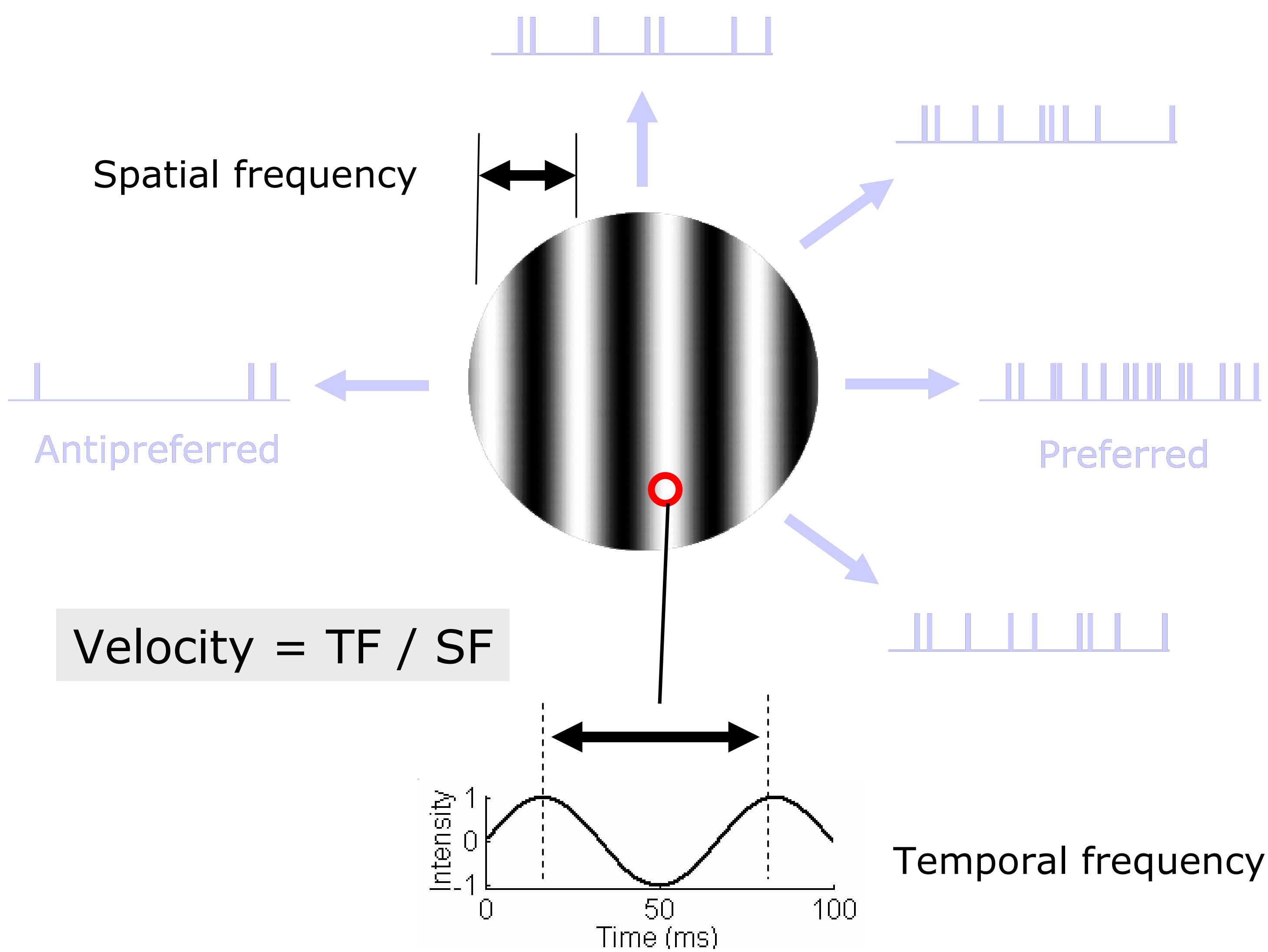


Nover et al. (2005)

Are fixed tuning curves an appropriate representation of the motion sensitivity of direction selective cells under more variable stimulus conditions?

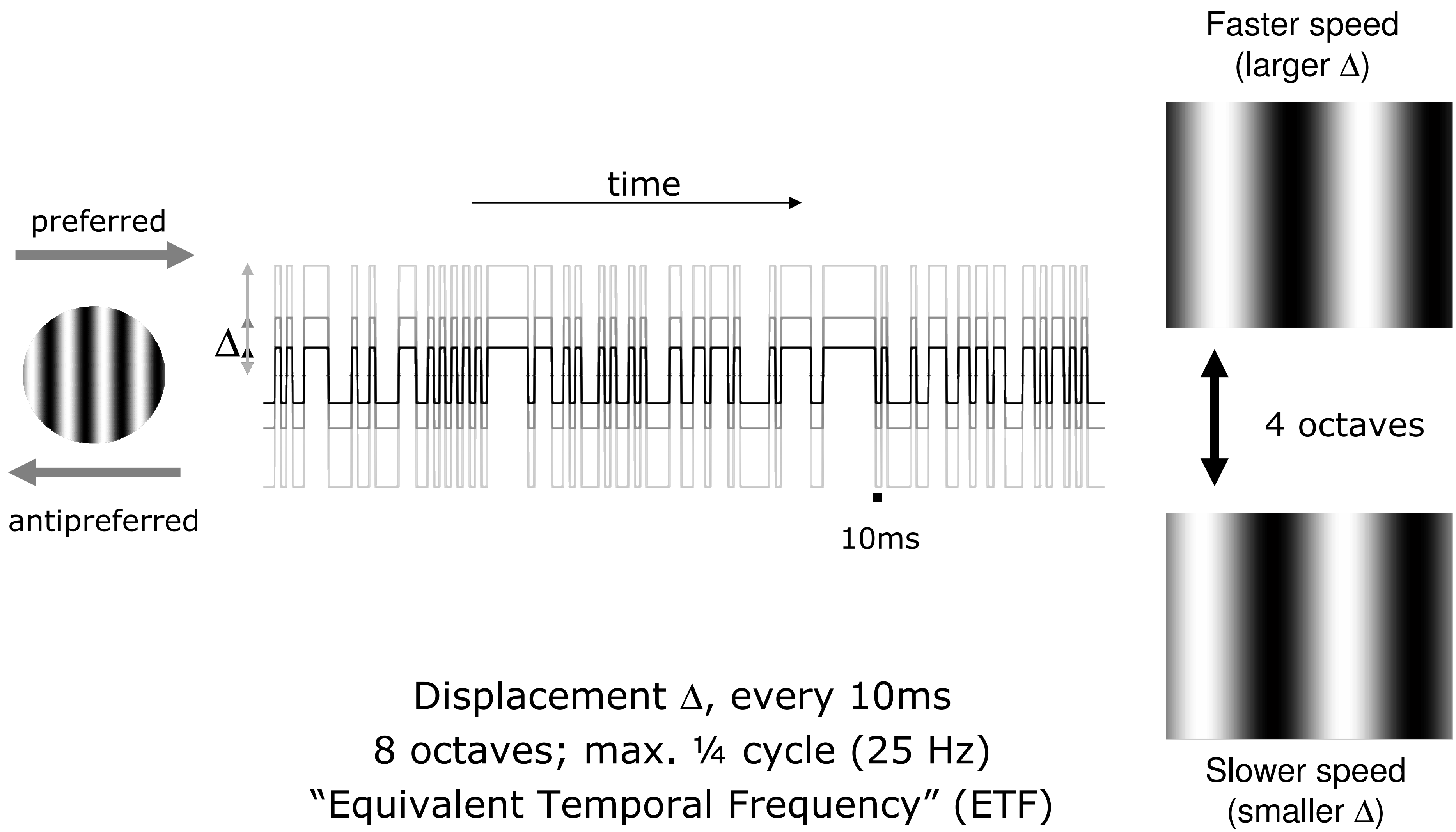
Direction Selective Cells in Visual Cortex





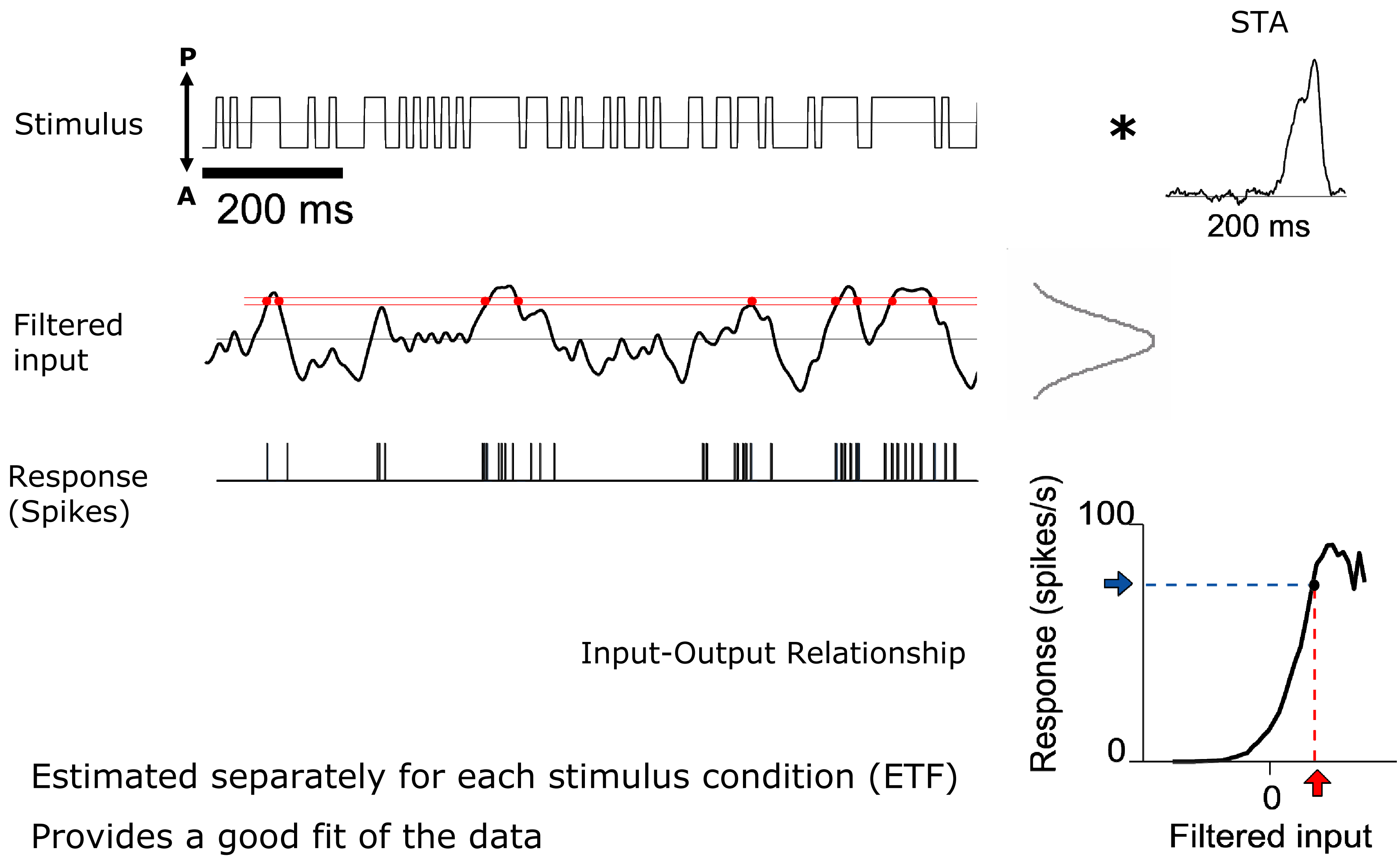
Binary Random Motion Stimulus

[All data recorded from DS cells in anaesthetized macaques]



Displacement Δ, every 10ms
8 octaves; max. ¼ cycle (25 Hz)
"Equivalent Temporal Frequency" (ETF)

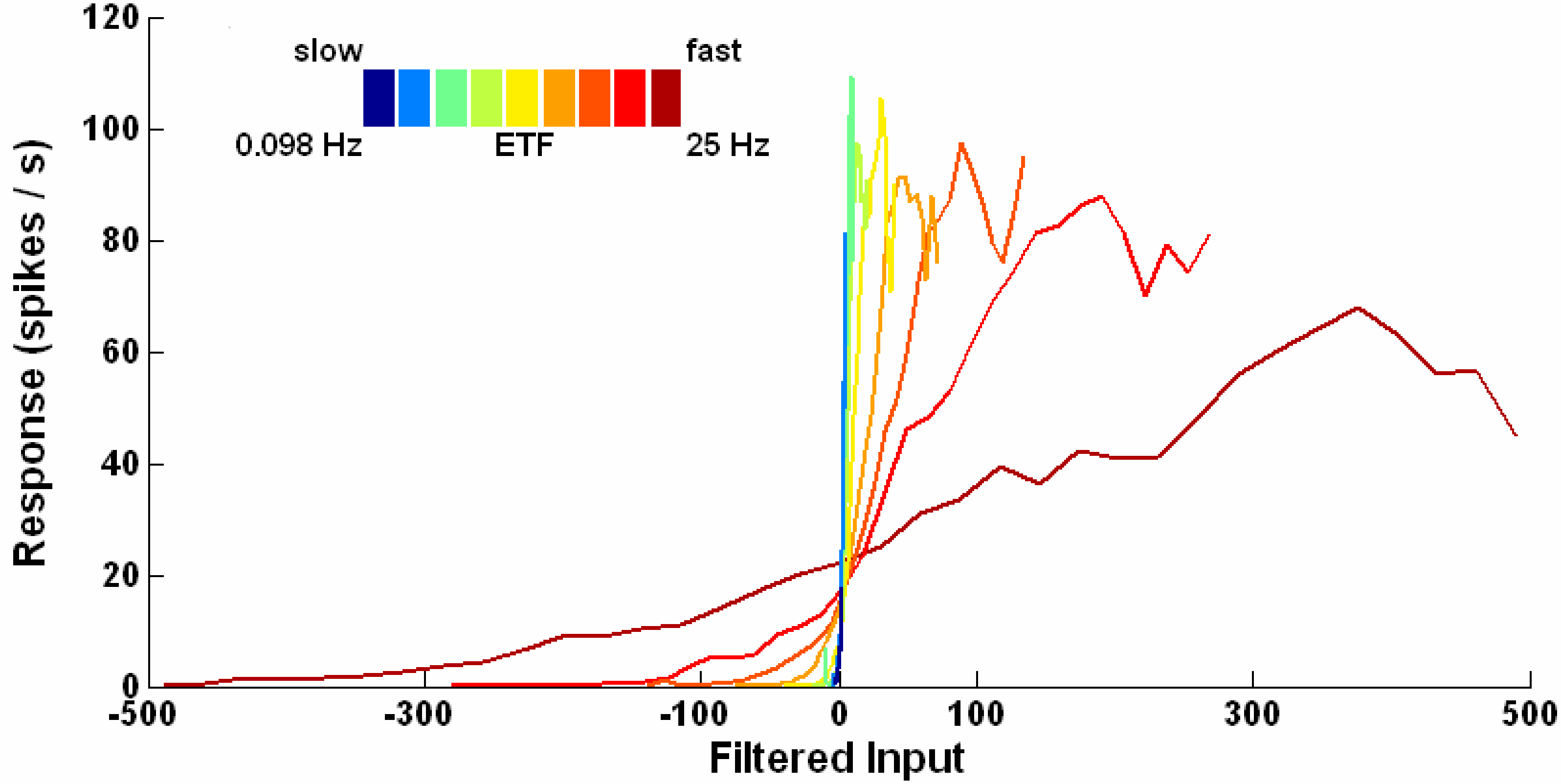
Input-Output Relationship



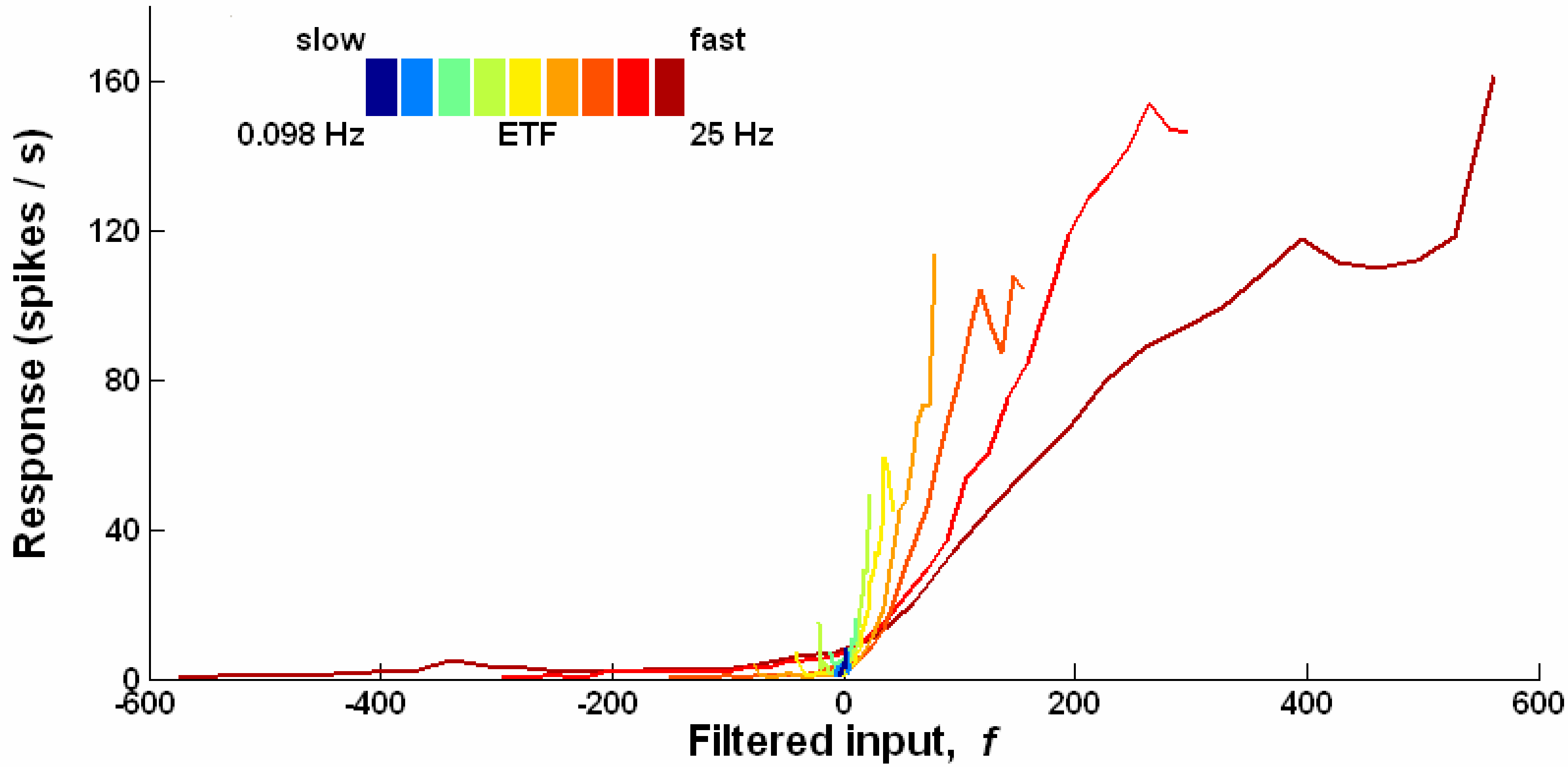
Estimated separately for each stimulus condition (ETF)

Provides a good fit of the data

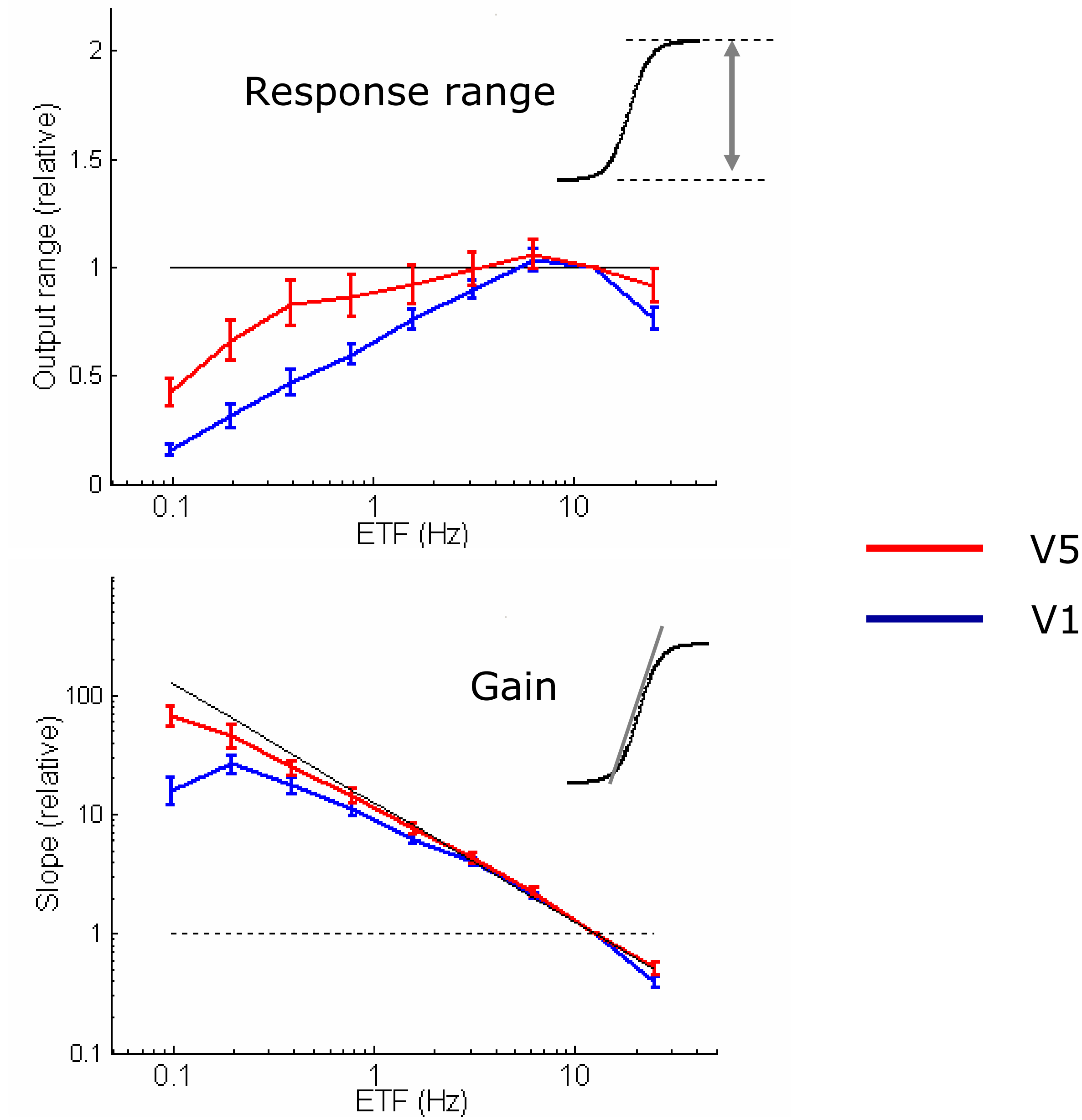
Example Cell (V1)



Example Cell #2 (V1)

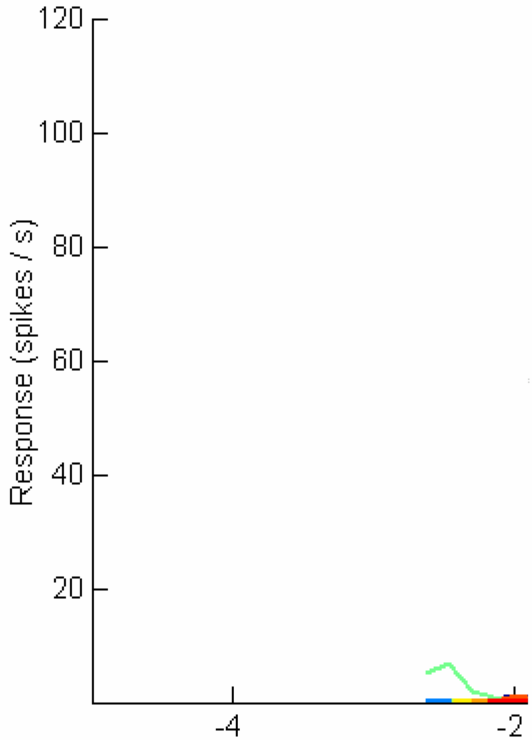


Gain & Range Changes Across the Population

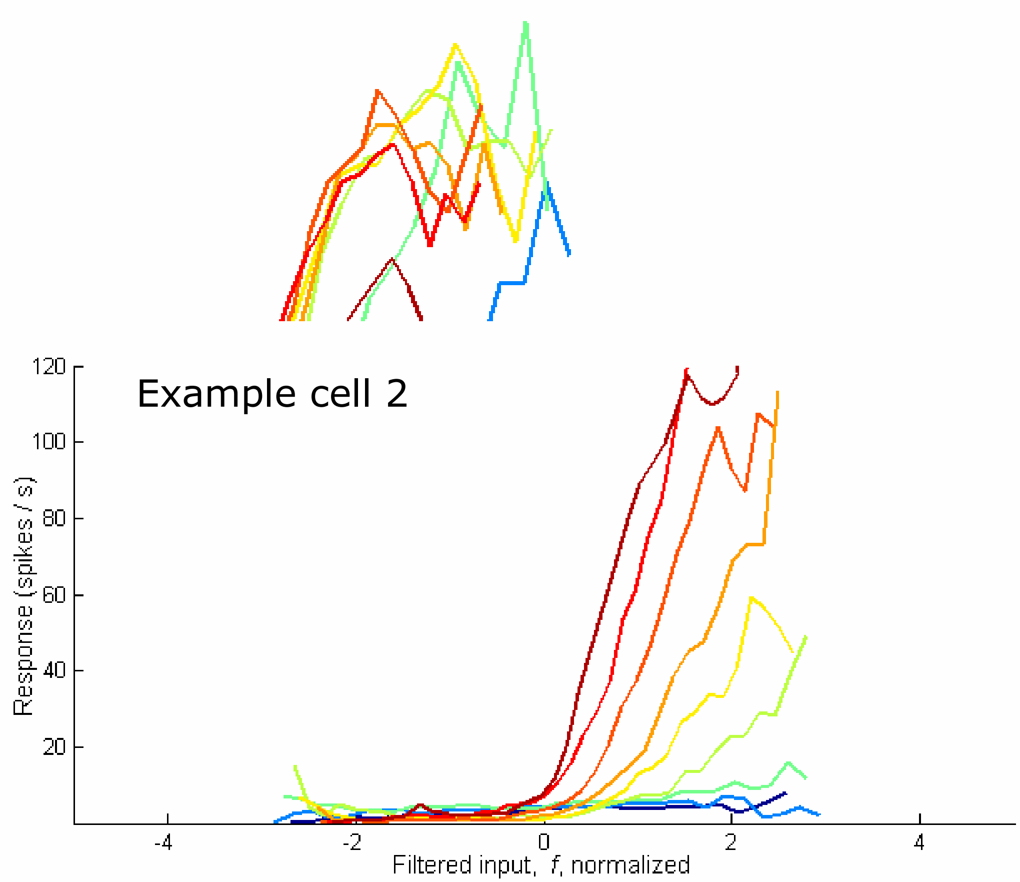


Constant "relative sensitivity"

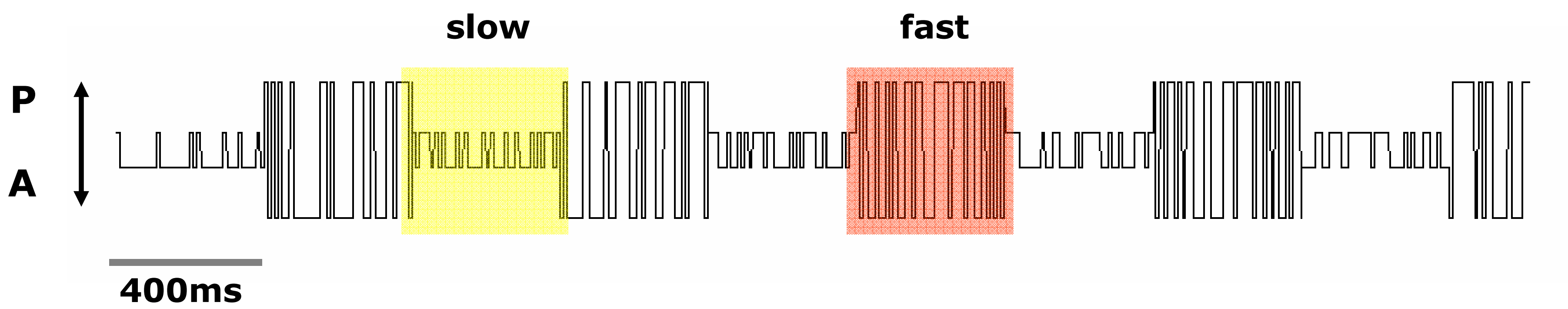
Example cell 1

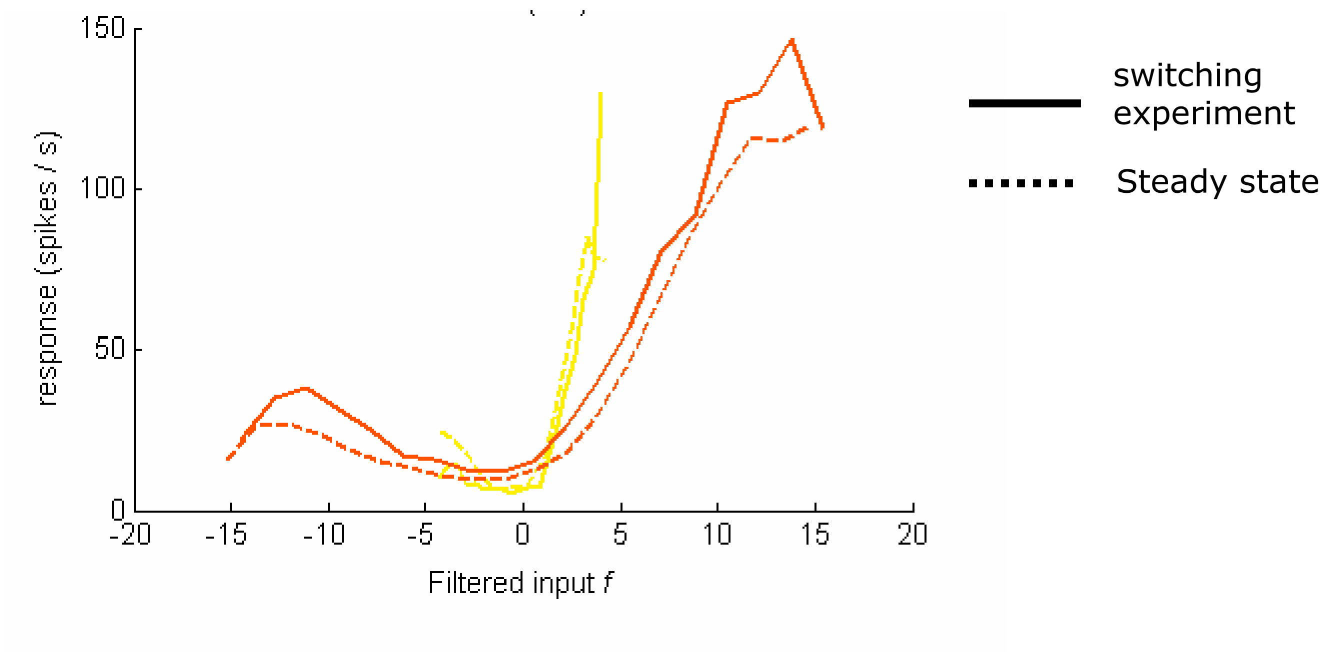


Example cell 2



Motion gain changes rapidly

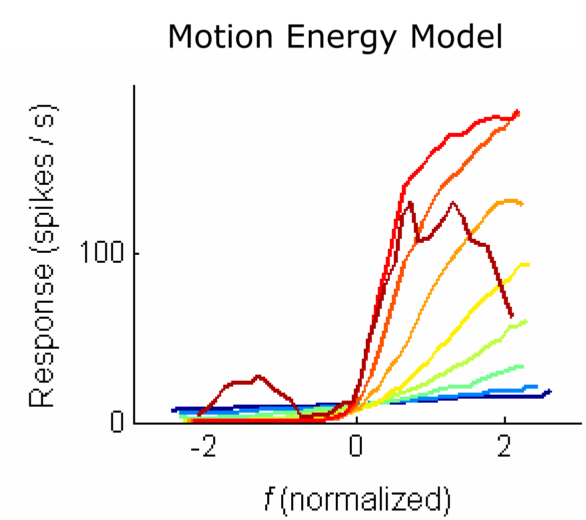


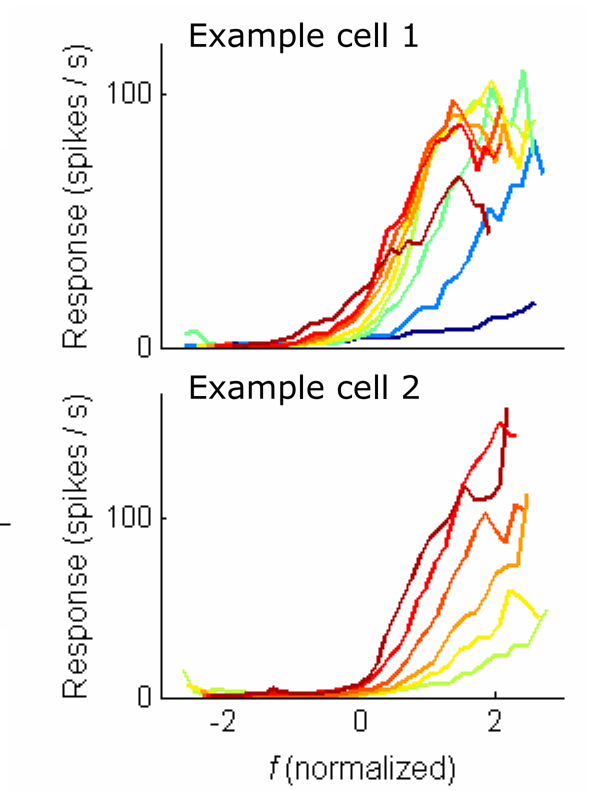


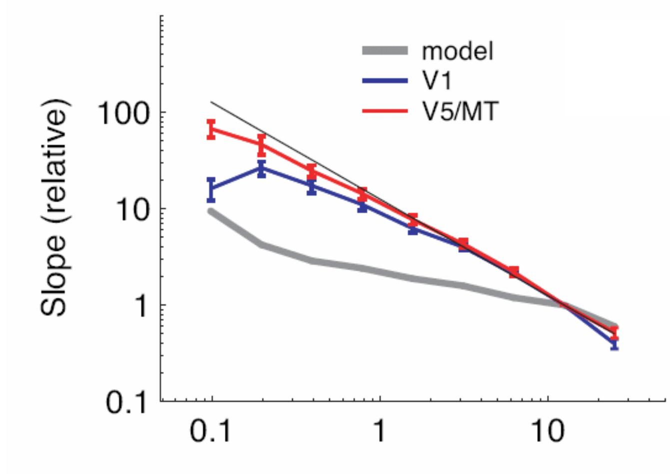
There is also a slow component – but it is very weak in comparison

Gain control in models of motion detection

Motion Energy Model with conductance based LIF spike generation…



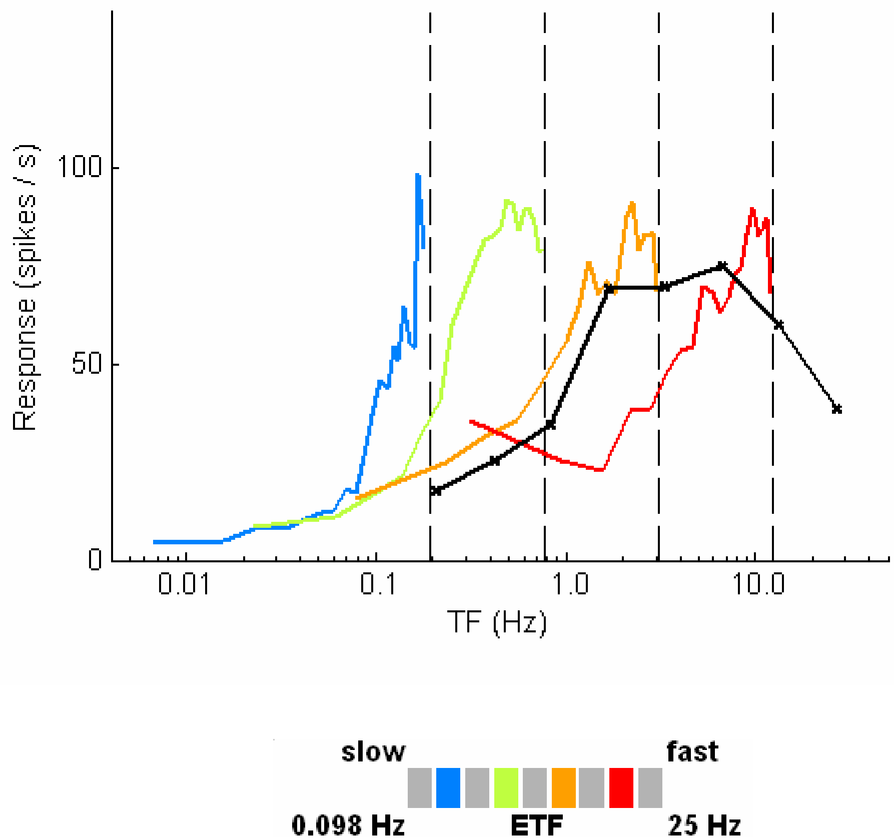




…explains only a portion of the change in gain

…see also: Borst et al. (2005)

Tuning curves revisited…



Summary & Conclusions

- A *random motion stimulus* suggests that motion encoding by DS cells is highly context dependent (here: variance)
  - Change in *temporal integration* (Bair & Movshon, 2004)
  - Change in *gain (IO relationship)*

$\Rightarrow$ Direction selective cells seem to be poorly characterized by a single input-response (tuning) curve

- Potentially functionally beneficial
  - Allows to encode stimulus values efficiently over a broad range
  - High gain compensates for weak signal (slow stimulus)

- But what about the resulting ambiguity?
  - Seems to be hard to reconcile with the idea of labeled-line models

Summary & Conclusions (contd.)

- Results are surprisingly consistent with studies in other species and other sensory modalities
  Brenner et al (2000), Fairhall et al (2001)*, Borst et al (2005) (fly, motion); Chander & Chichilnisky (2001), Kim & Rieke (2001), Baccus & Meister (2002) (retina, contrast) Dean et al (2005), Nagel & Doupe (2006) (sound intensity) Maravall et al., 2007 (whisker deflections);* **Adam Kohn (motion, monkey)**
  See also Ringach & Malone (2007) for related results

- BUT:
  - the effect is *very* different from classical adaptive phenomena (e.g. cortical contrast gain control)
  - Perhaps better described as an "*adaptive nonlinearity*"

- And of course:
  - The linear-nonlinear model is still a very limited description of the cells' response properties

- Open questions:
  - Underlying mechanism(s)?
  - How would such a representation be read out?