Fundamentals of area V1
Part 2: Filtering, Gain Control, Feedback

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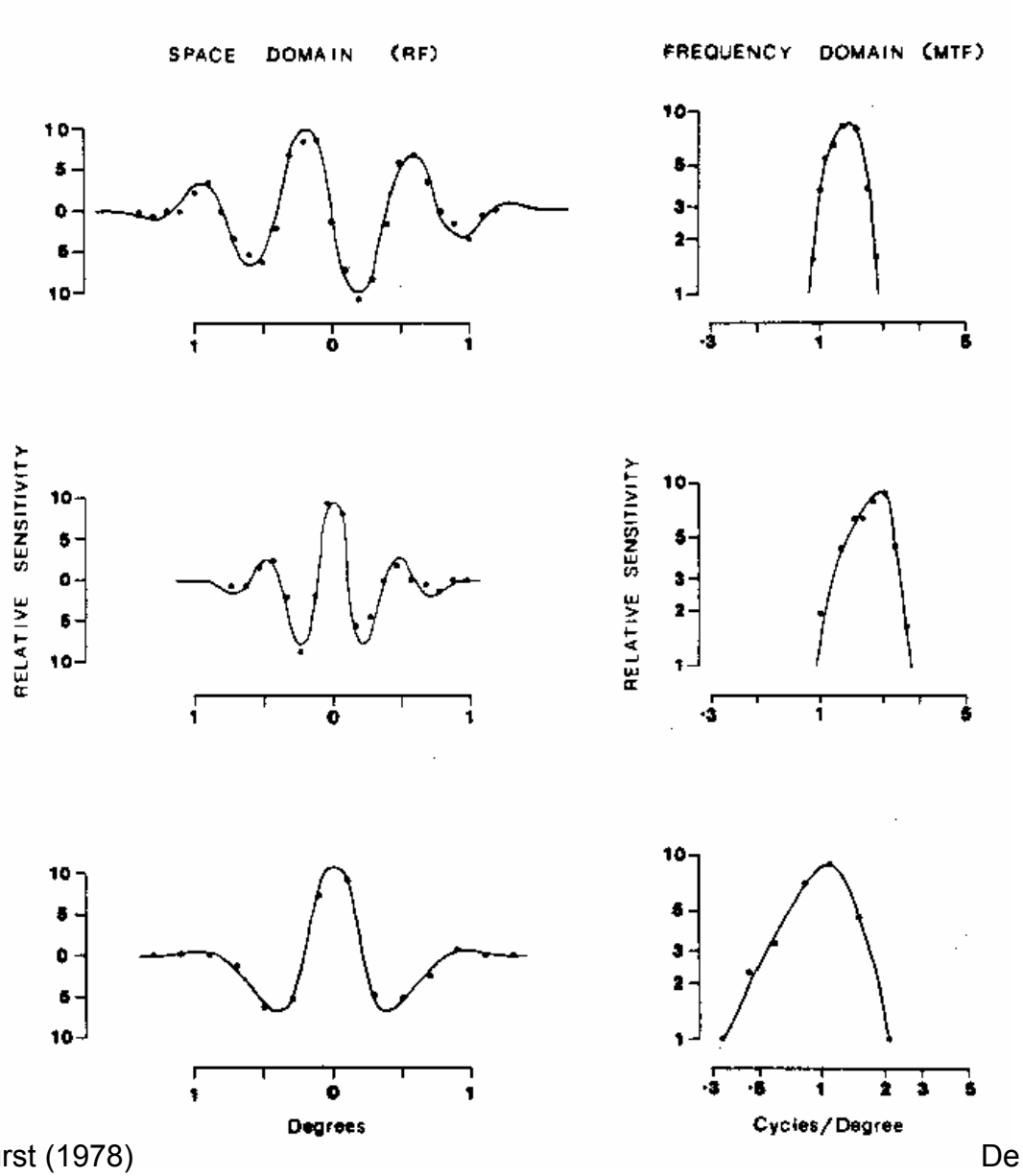
Linear model of V1 simple cells

Responses are a weighted average of the stimulus intensity; the receptive field is the map of the weights.

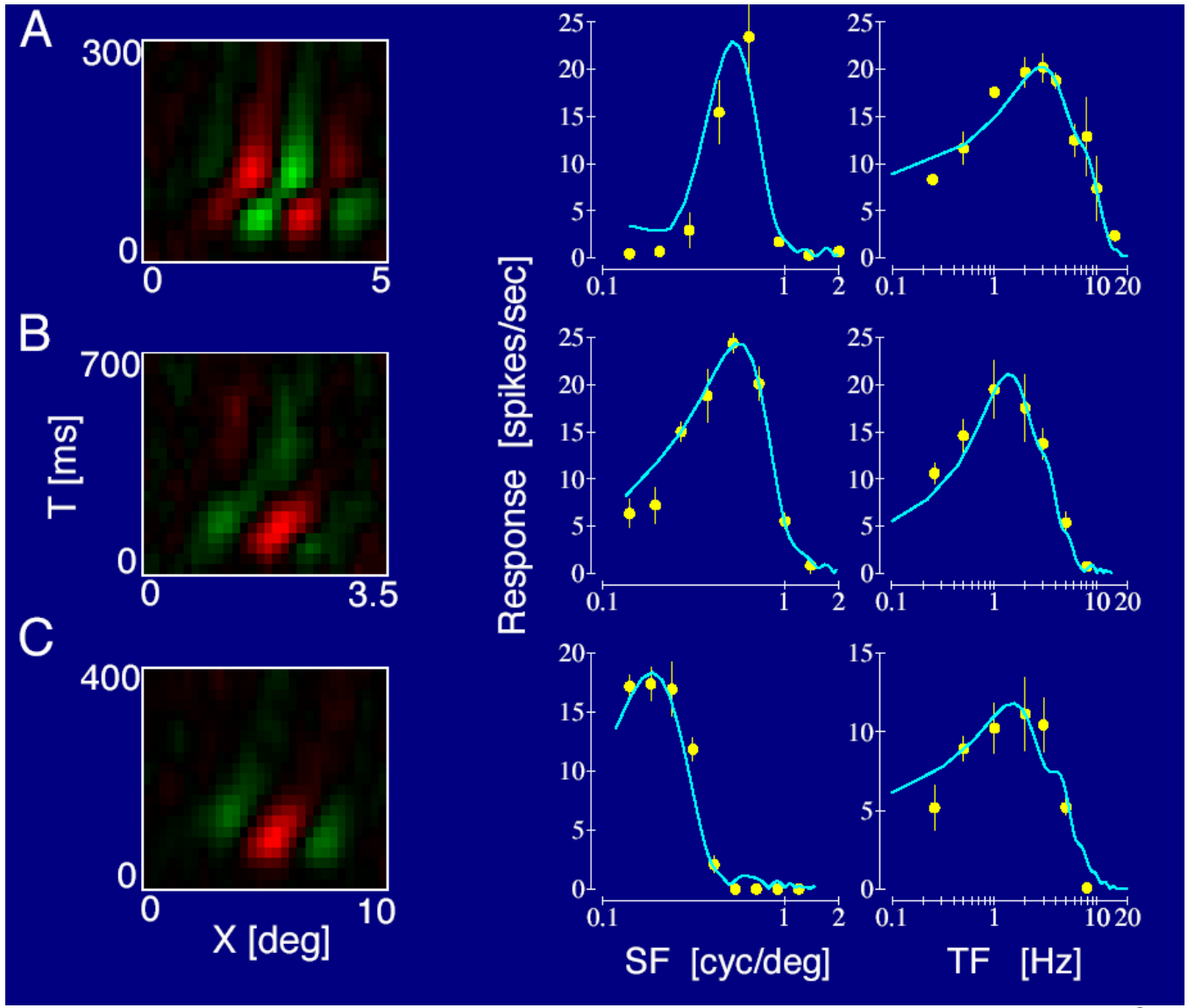
Linear model predicts spatial selectivity



Movshon, Thompson & Tolhurst (1978)

Albrecht (1978)
De Valois & De Valois (1990)

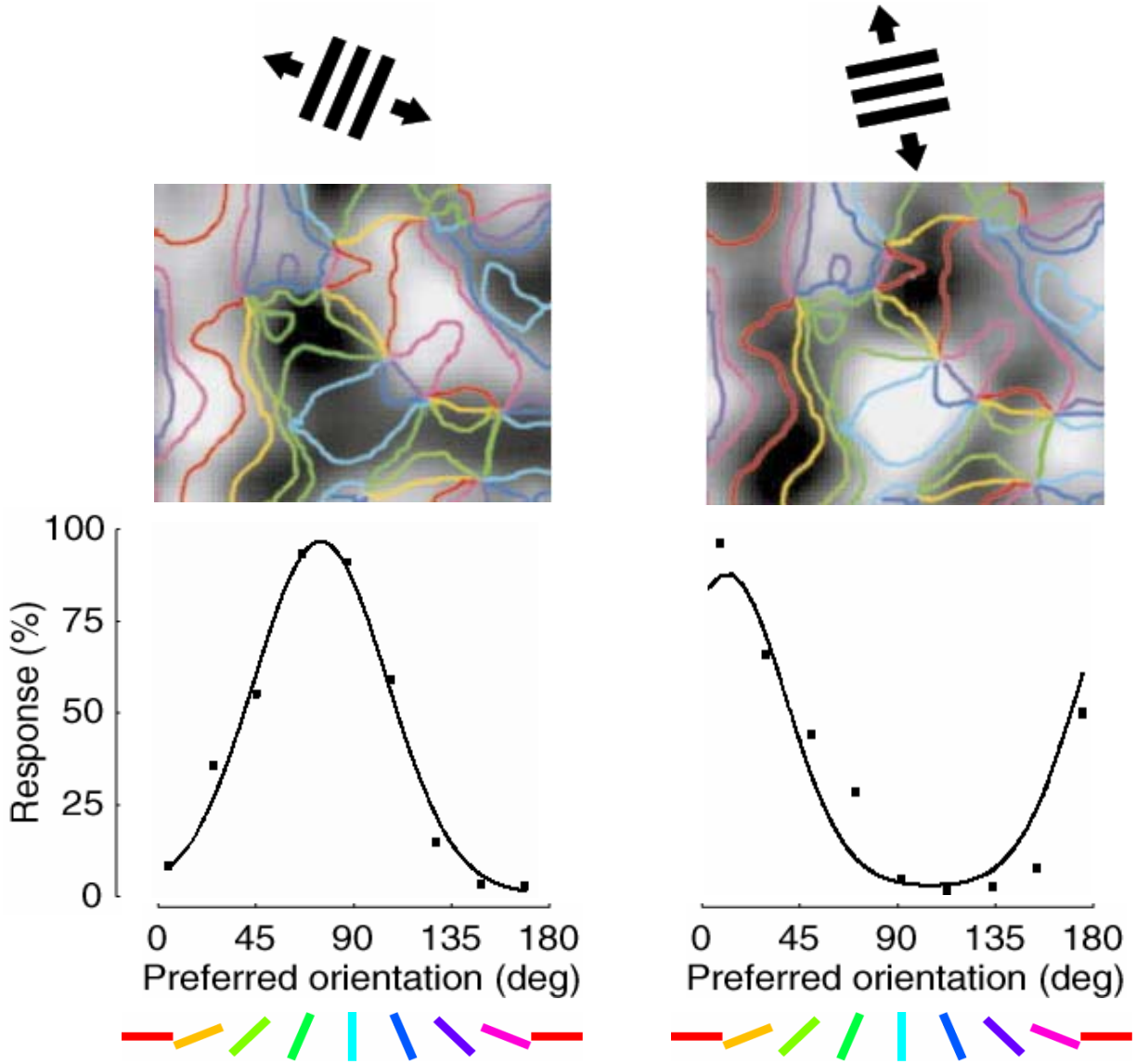
Linear model predicts spatiotemporal selectivity



DeAngelis, Ohzawa, Freeman (1993)

An application of these ideas

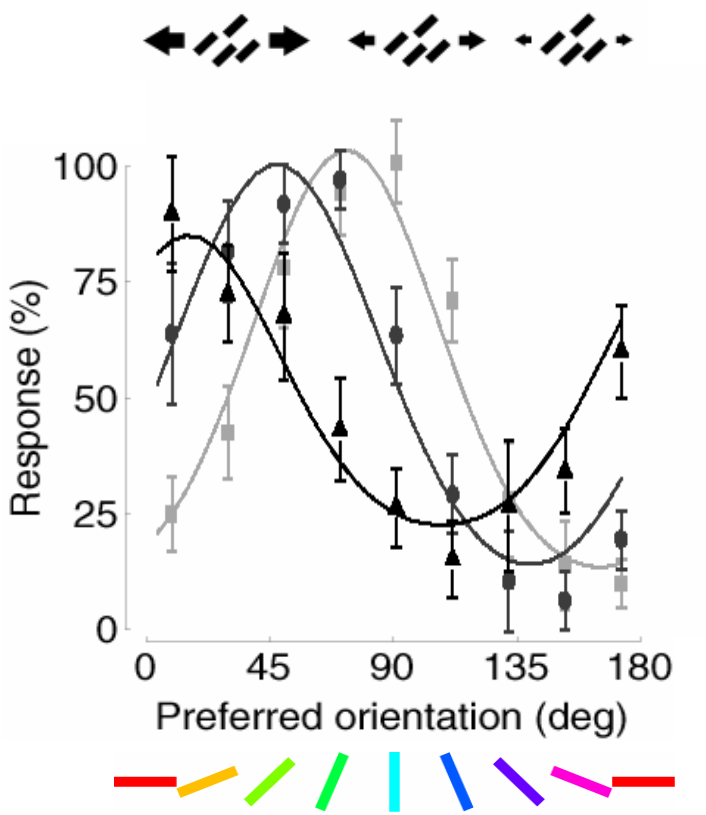
Single condition maps



Bonhoeffer & Grinvald, 1991

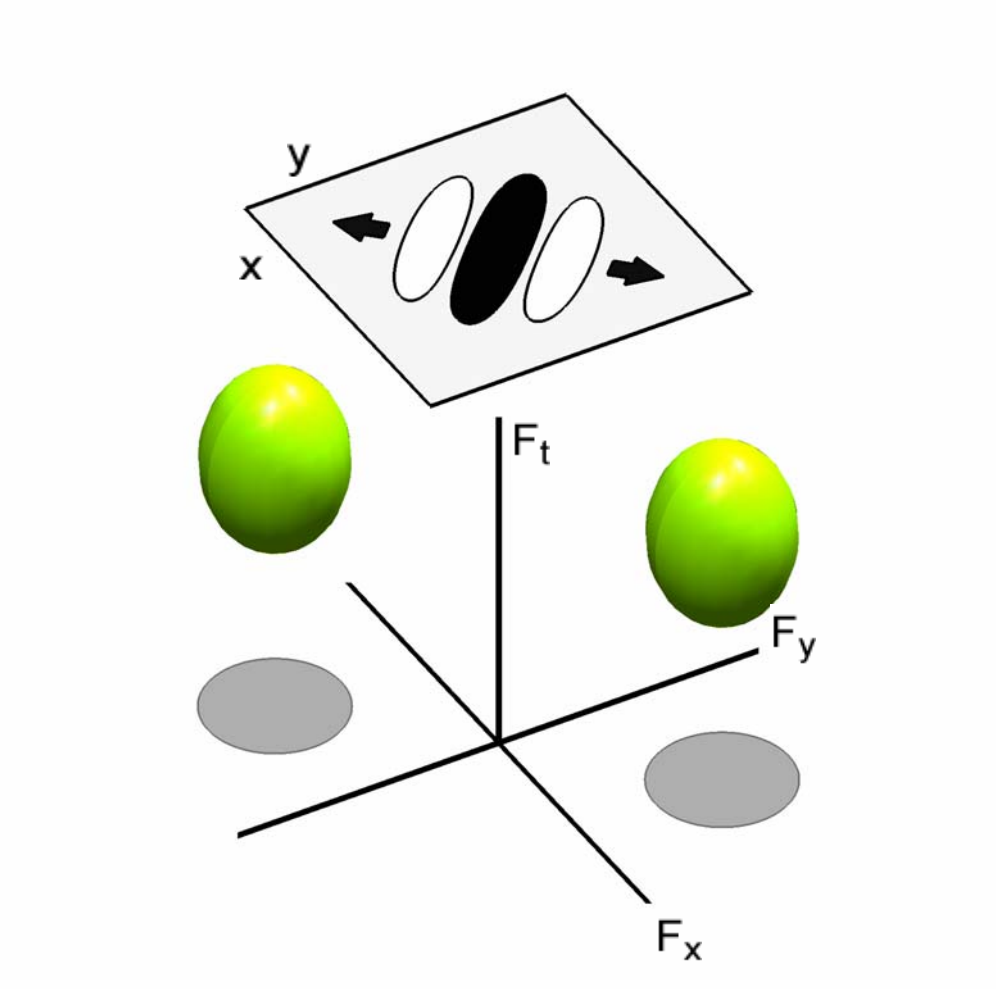
Basole, White & Fitzpatrick, 2003

Orientation depends on speed?



Basole, White & Fitzpatrick, 2003

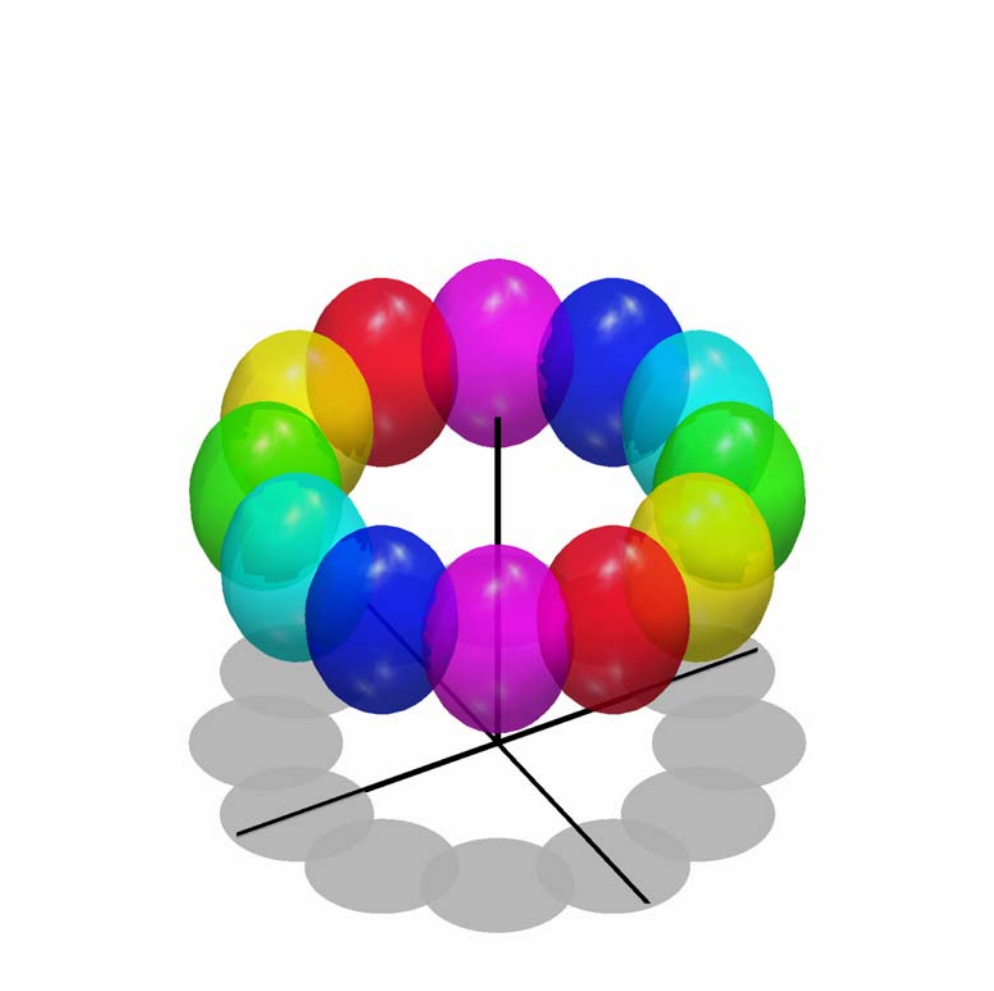
Receptive fields in frequency space



Watson & Ahumada, 1983

Mante & Carandini, 2004

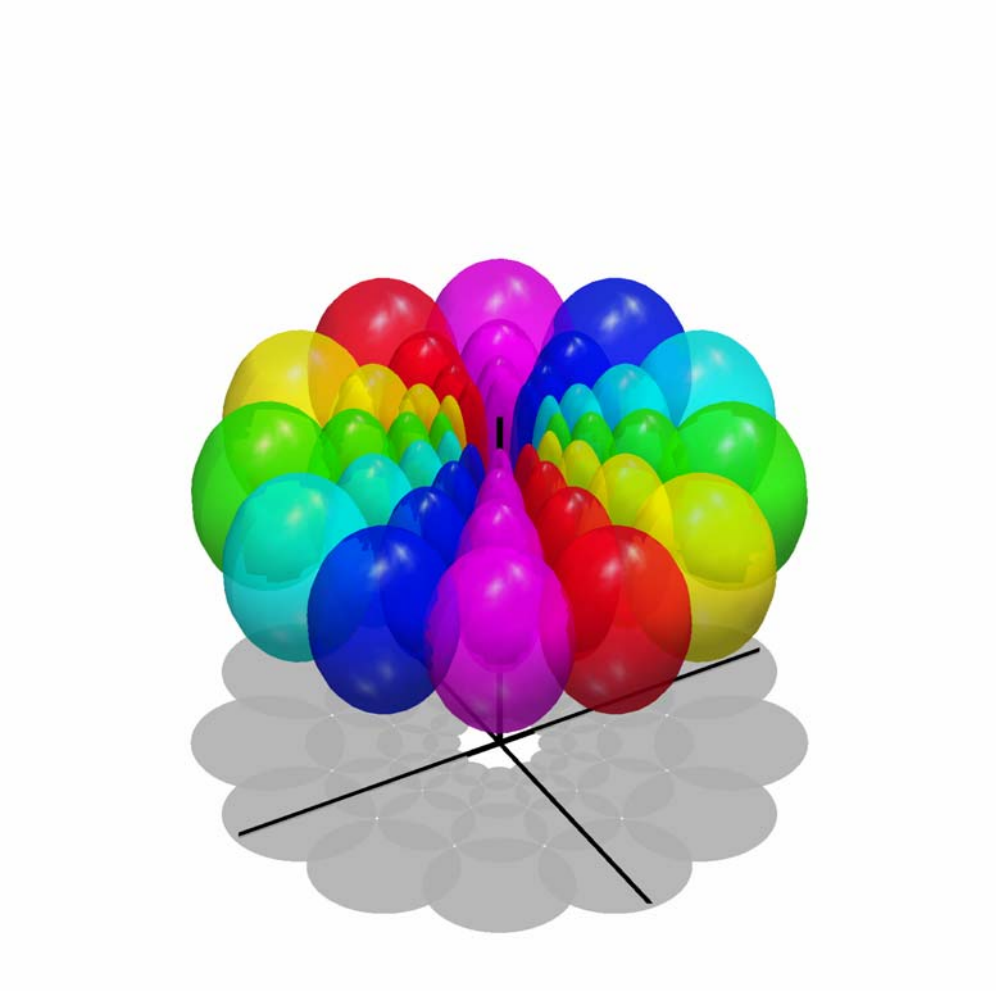
Receptive fields in frequency space



Watson & Ahumada, 1983

Mante & Carandini, 2004

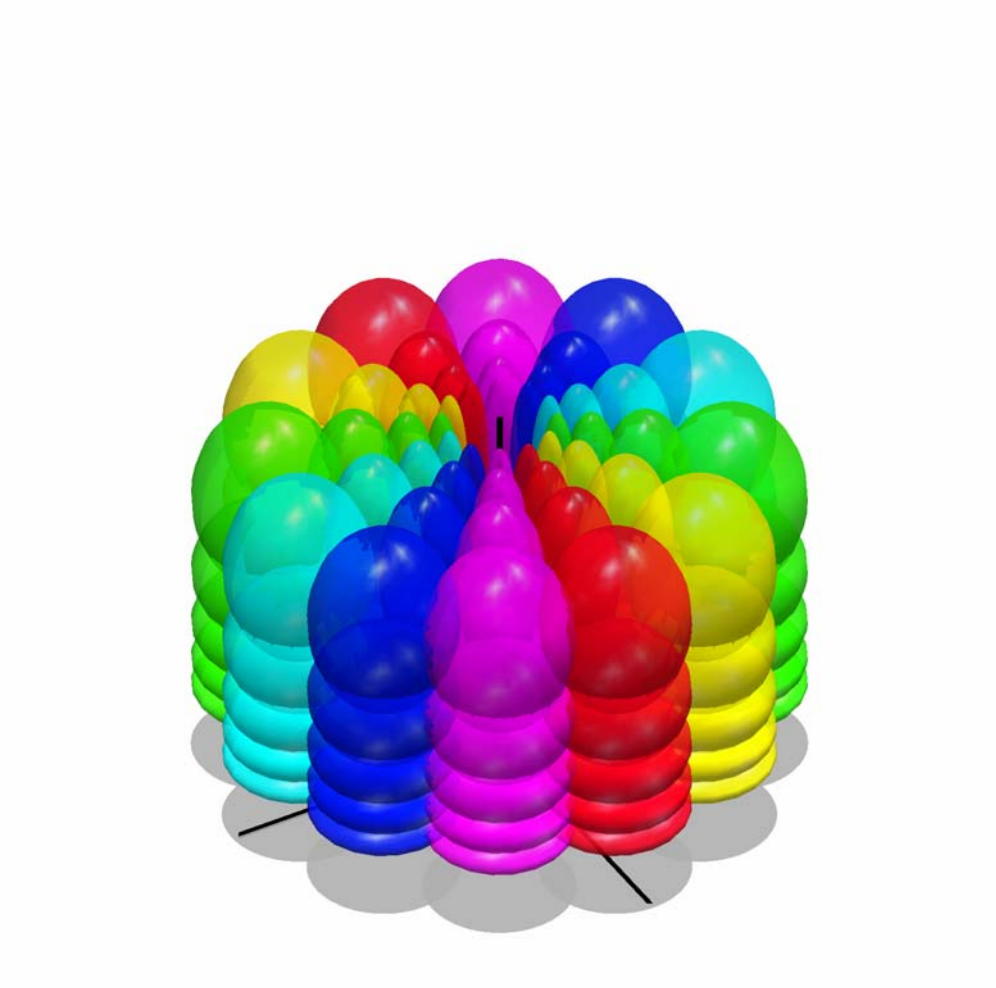
Receptive fields in frequency space



Watson & Ahumada, 1983

Mante & Carandini, 2004

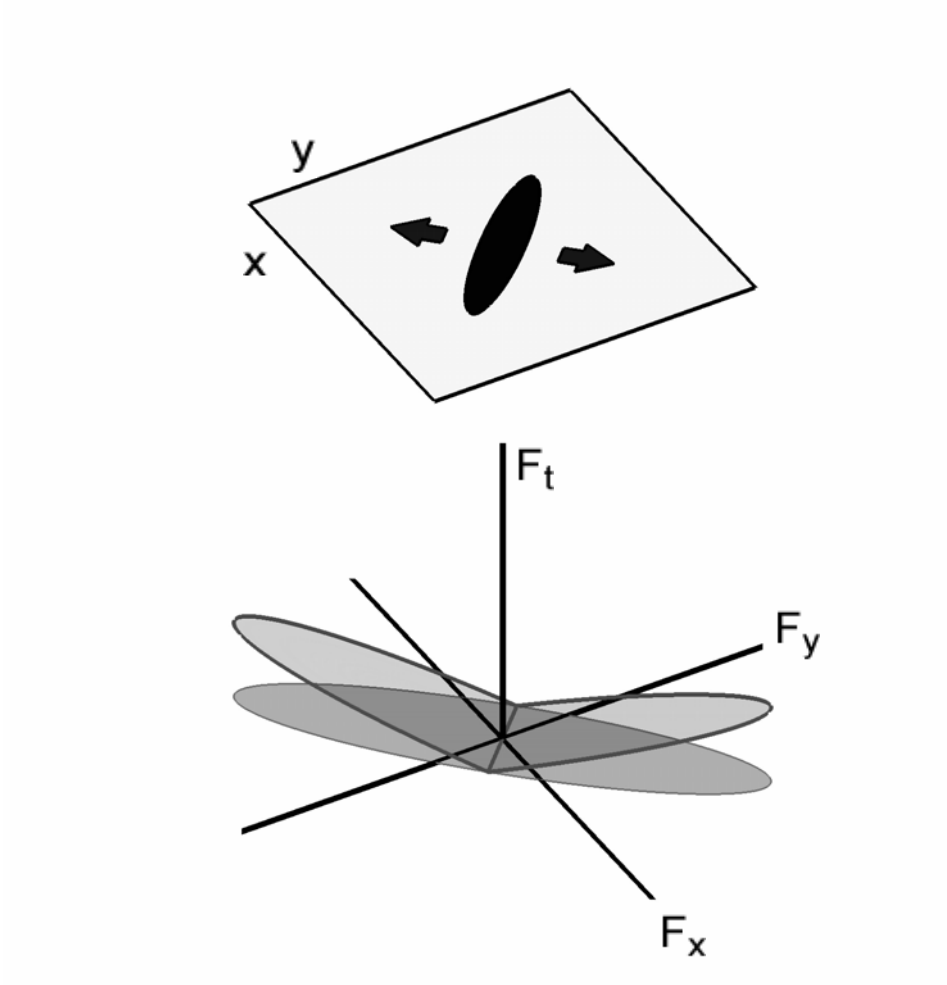
Receptive fields in frequency space



Watson & Ahumada, 1983

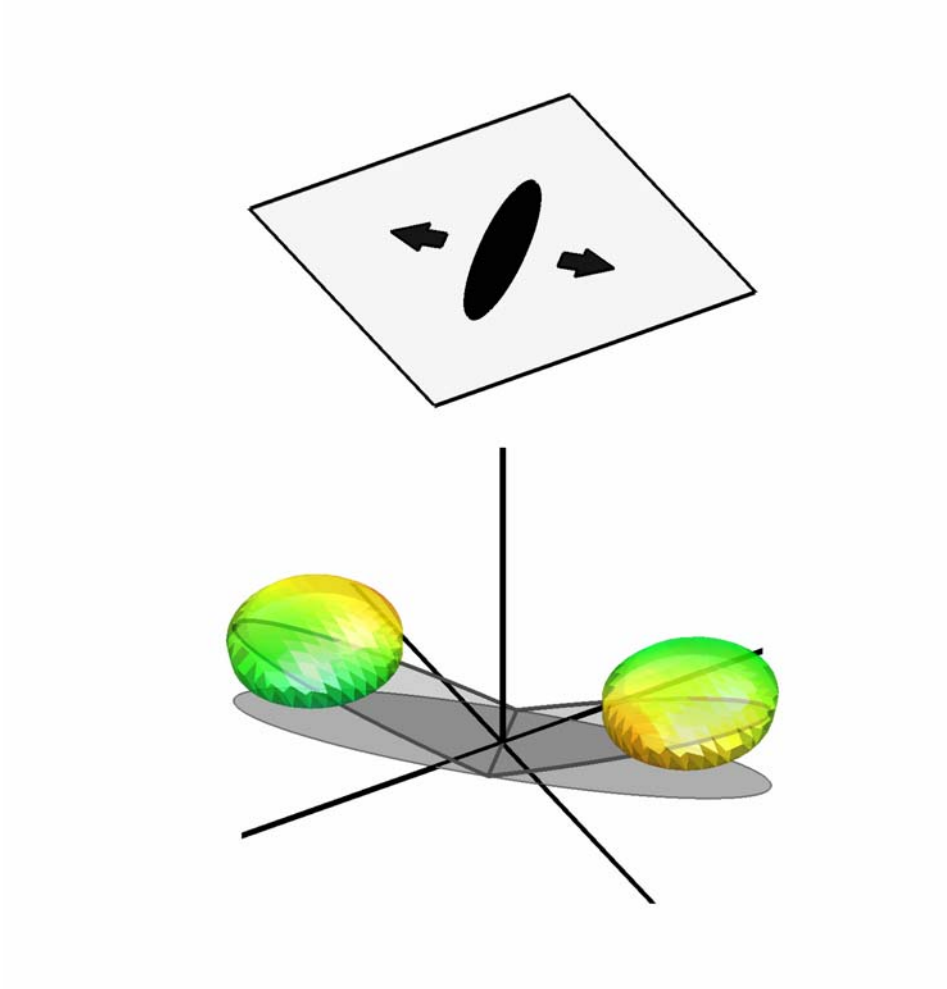
Mante & Carandini, 2004

A bar in frequency space



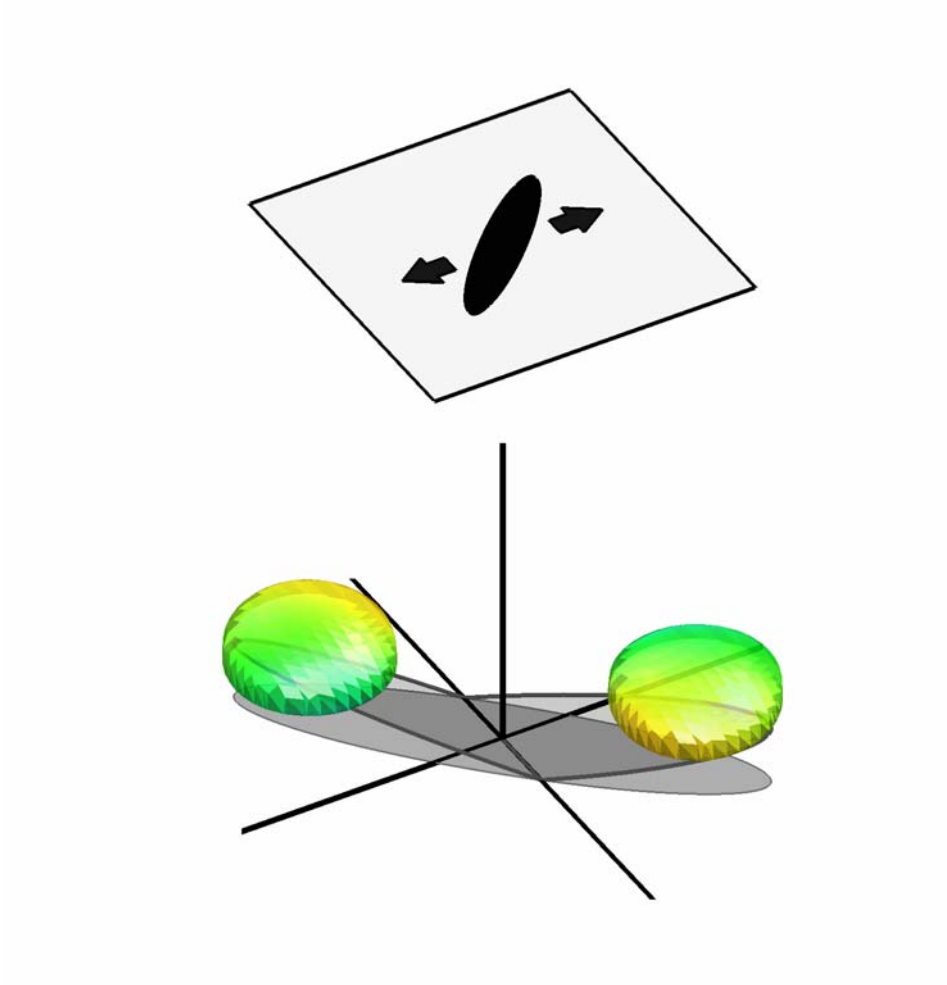
Mante & Carandini, 2004

Receptive fields stimulated by the bar



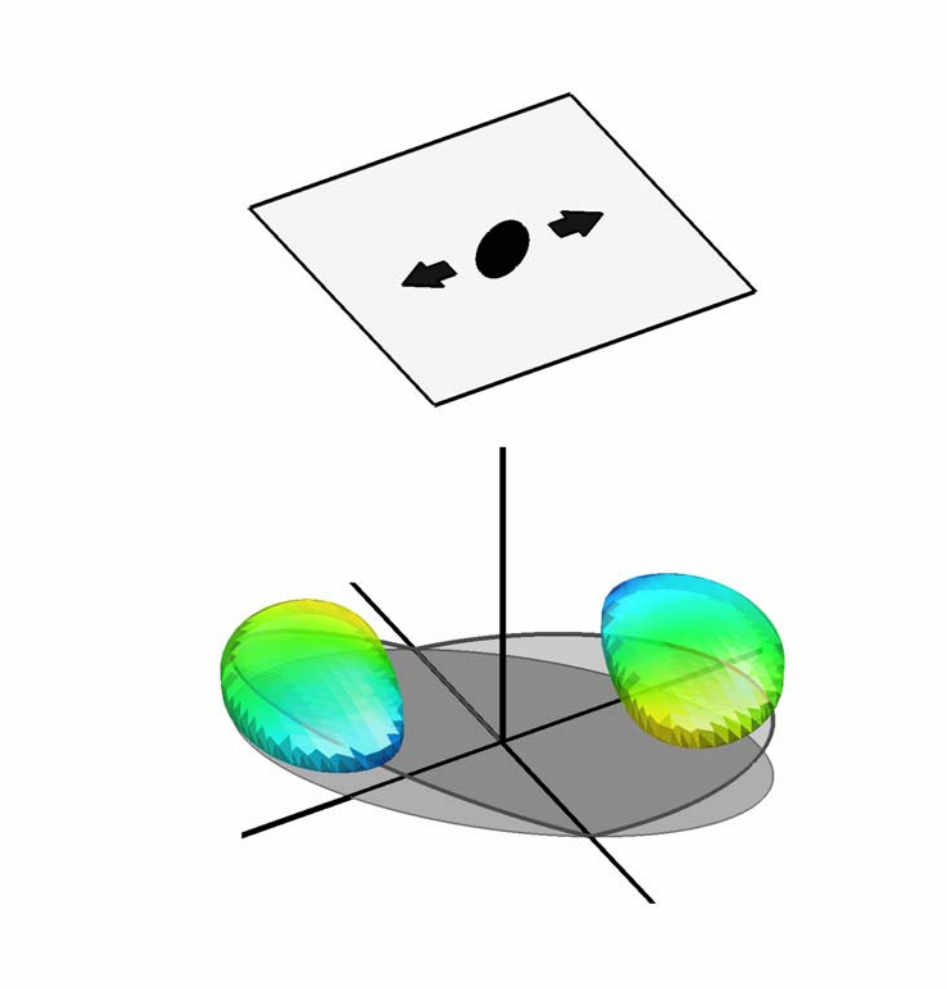
Mante & Carandini, 2004

Oblique motion



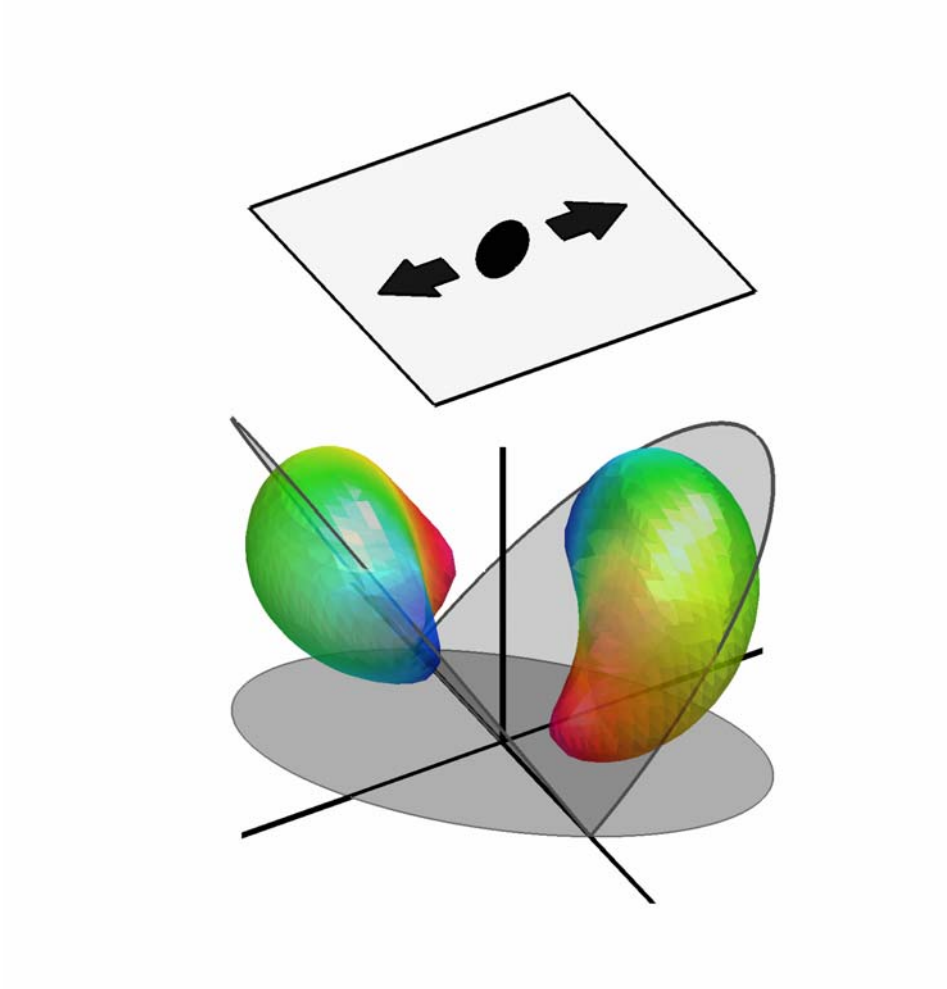
Mante & Carandini, 2004

Oblique motion: a short bar



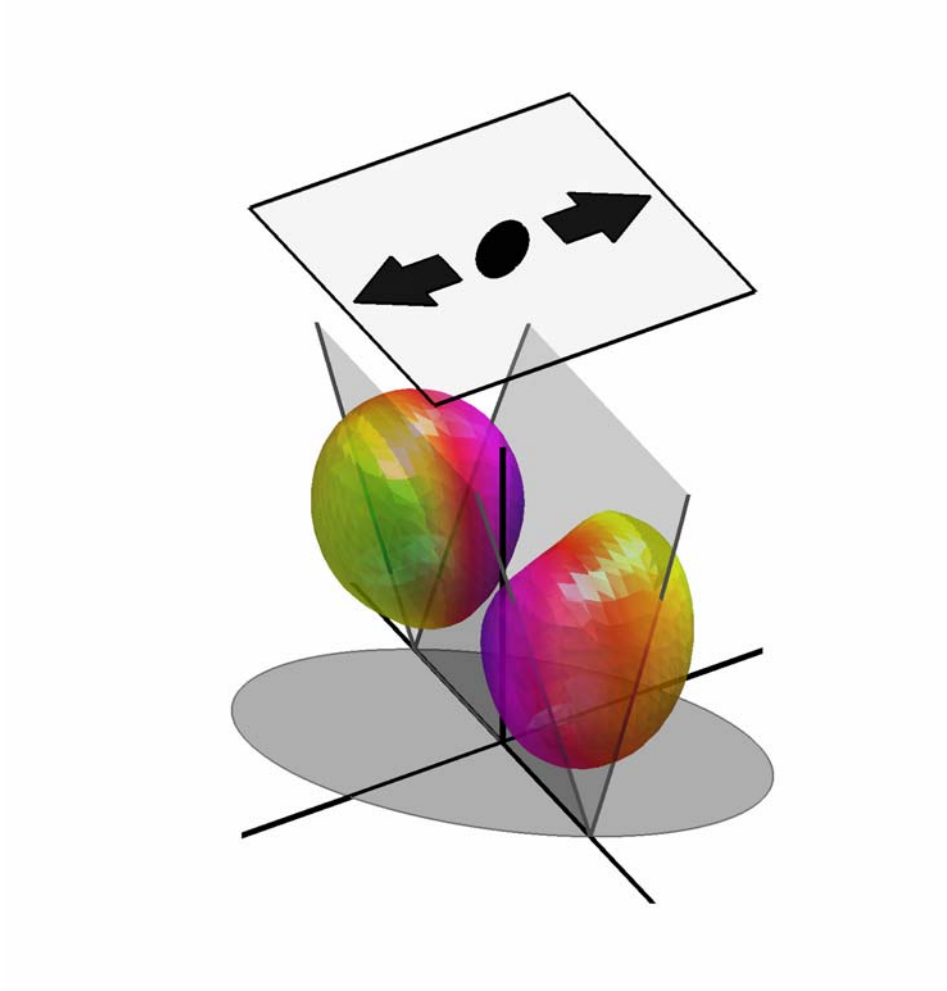
Mante & Carandini, 2004

Oblique motion: a faster bar



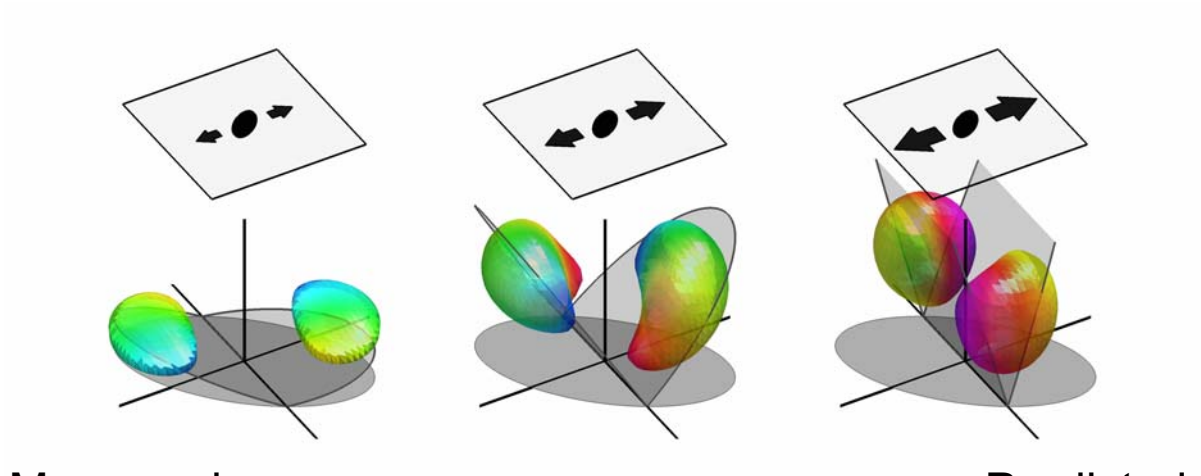
Mante & Carandini, 2004

Oblique motion: an even faster bar

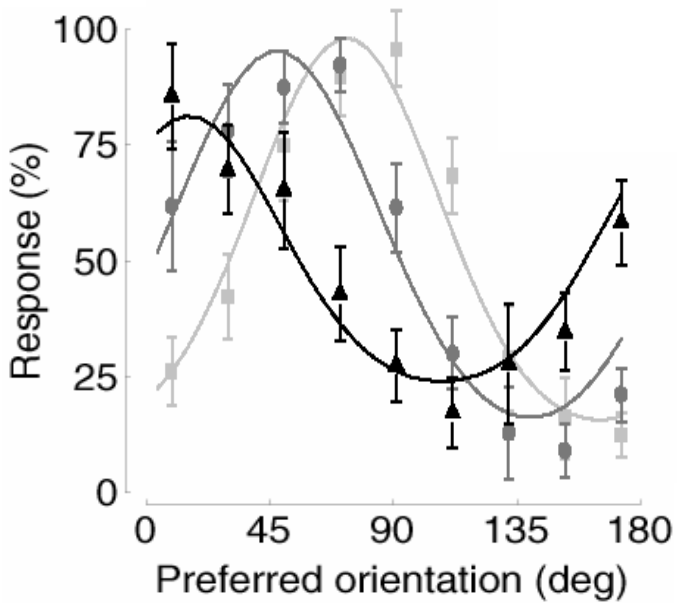


Mante & Carandini, 2004

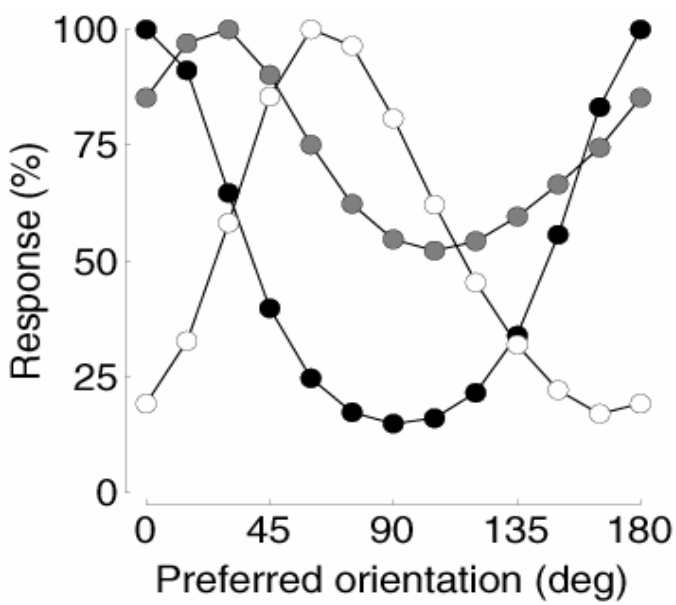
Effect of bar speed



Measured



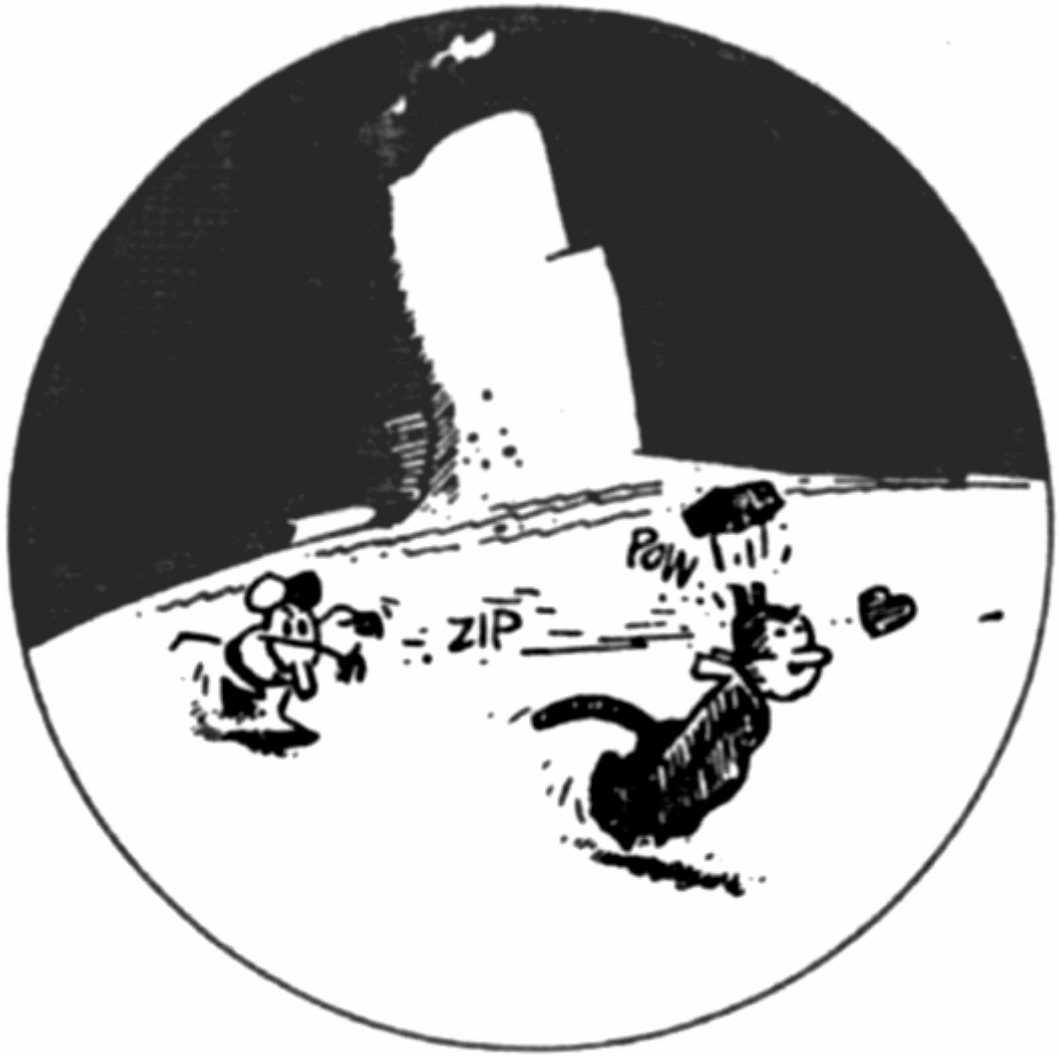
Predicted



Basole, White & Fitzpatrick, 2003

Mante & Carandini, 2004

Motion streaks



Geisler, 1999
Burr & Ross, 2002

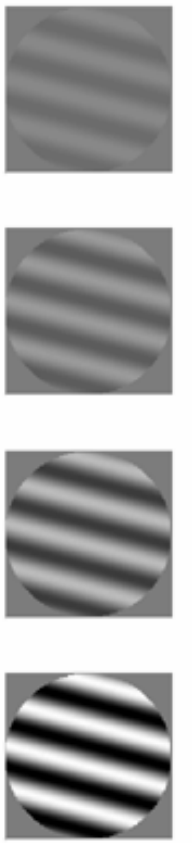
Nonlinearities in V1 responses

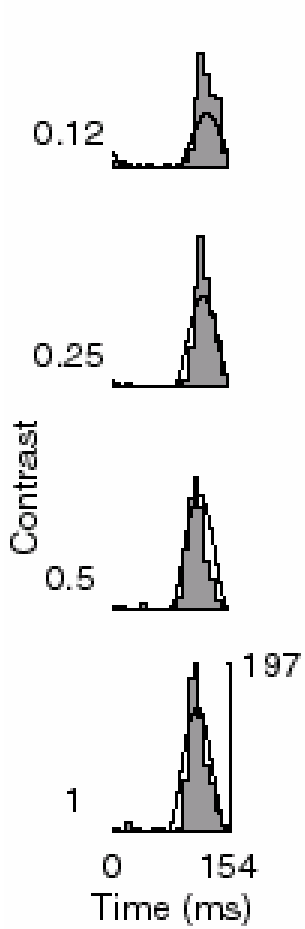
Nonlinearities in V1 responses

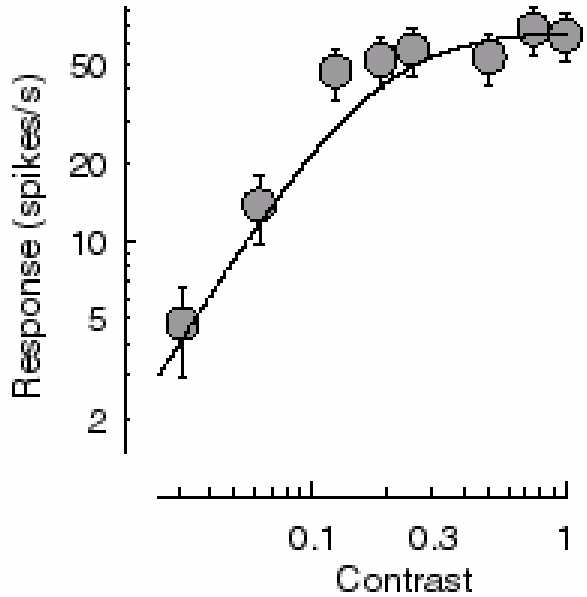
$$R = \frac{Lc}{c_{50} + kc}$$

Albrecht & Geisler (1991)
Heeger (1991)

Saturation

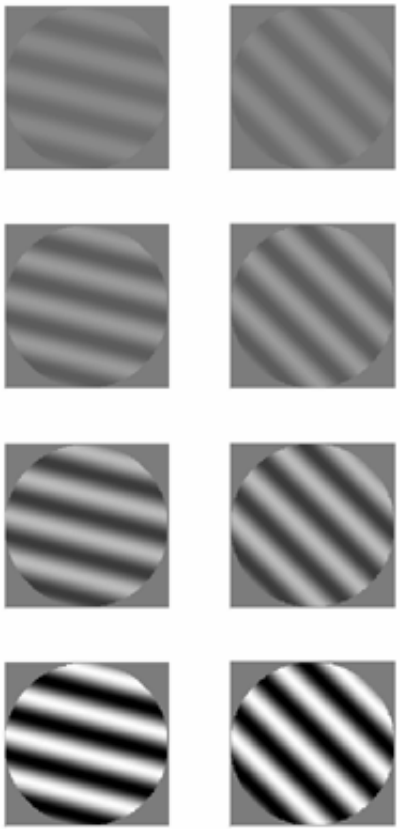


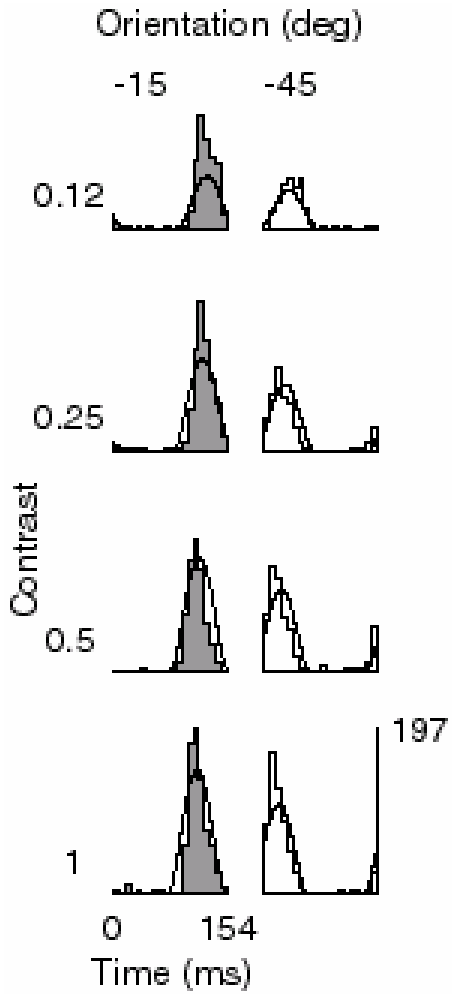


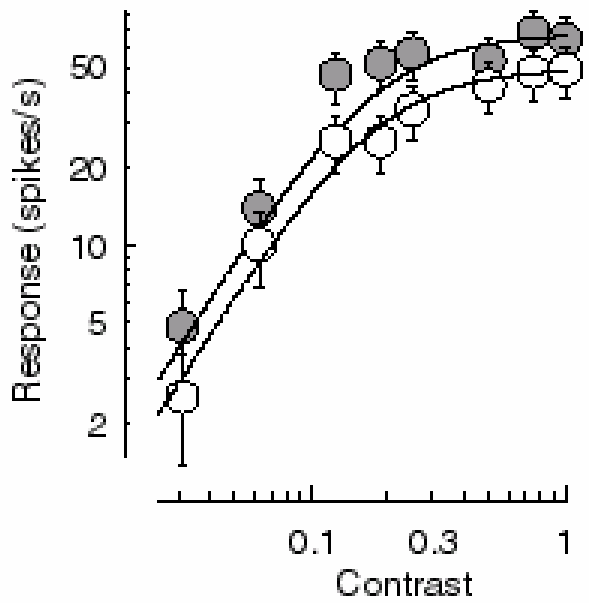


Carandini, Heeger & Movshon (1996)

Saturation depends on contrast

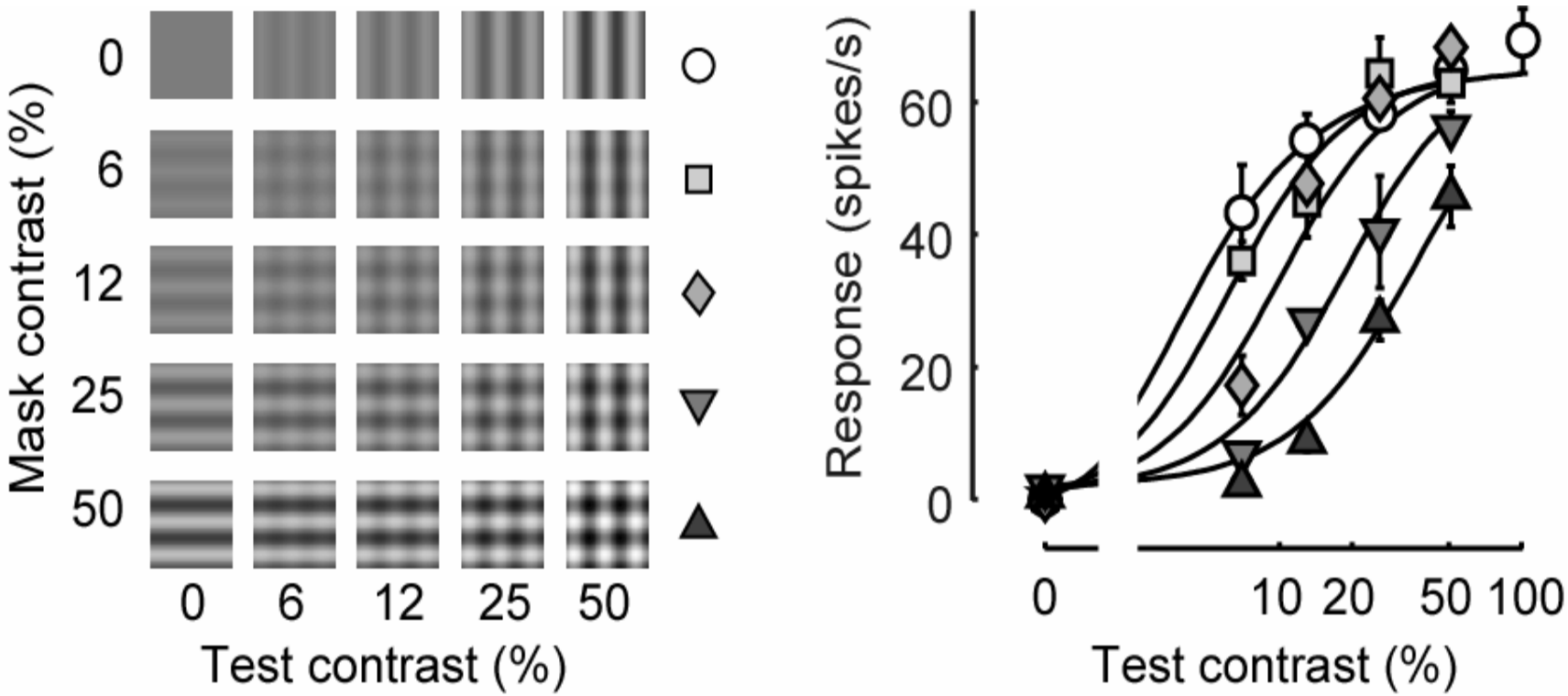






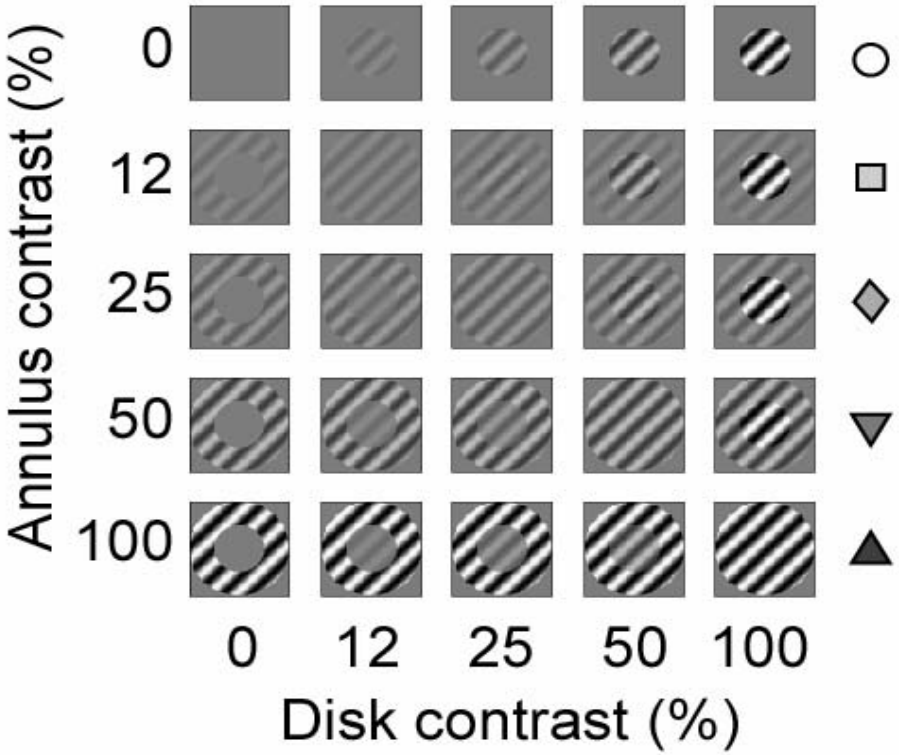
Carandini, Heeger & Movshon (1996)

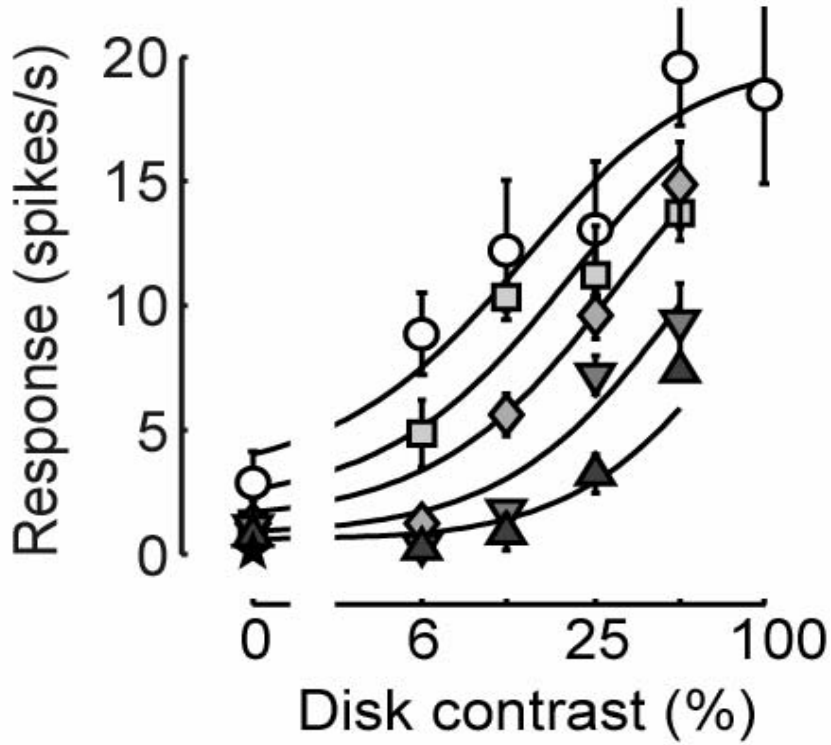
Cross-orientation suppression



Freeman, Durand, Kiper & Carandini (2002)

Surround suppression

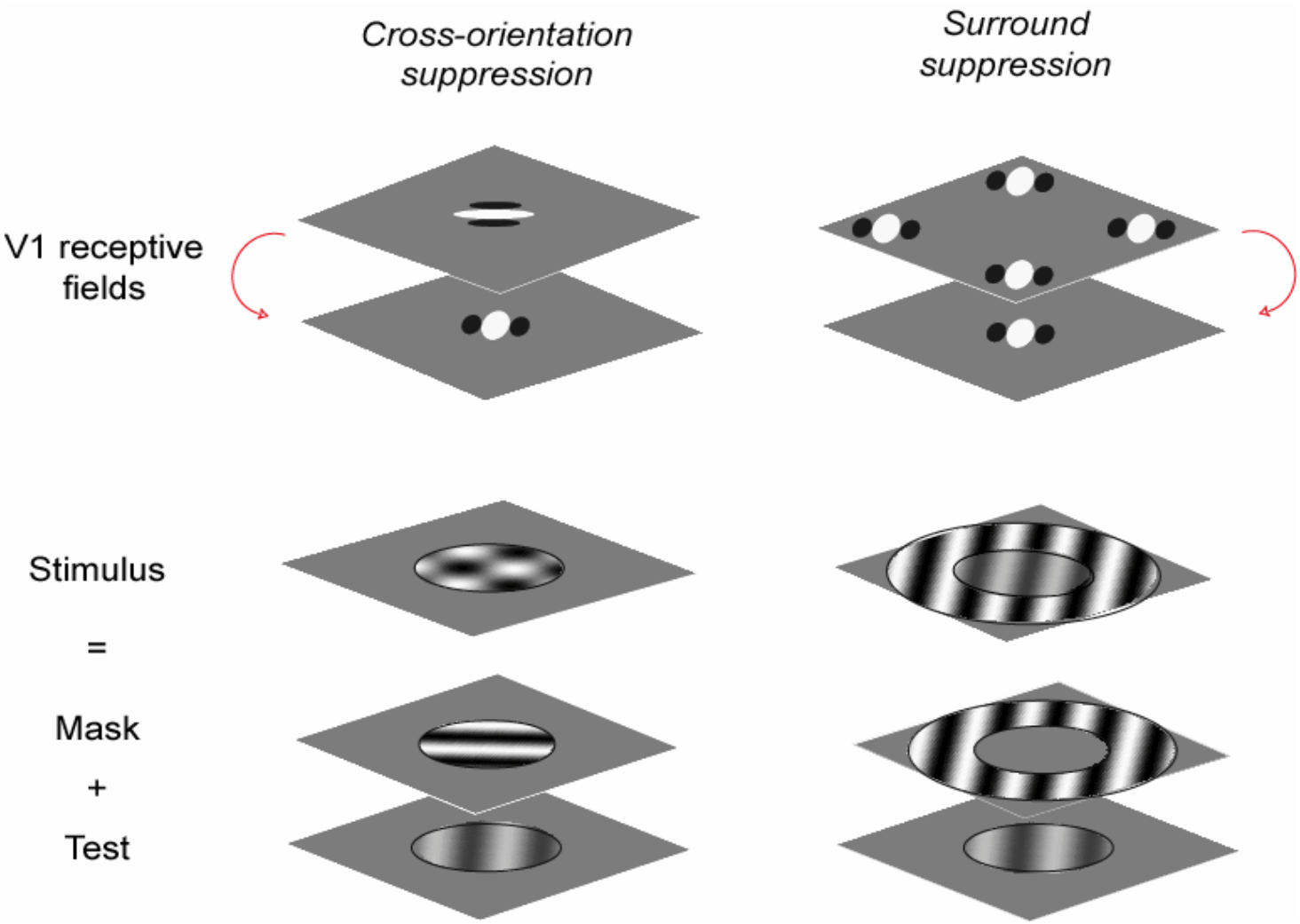




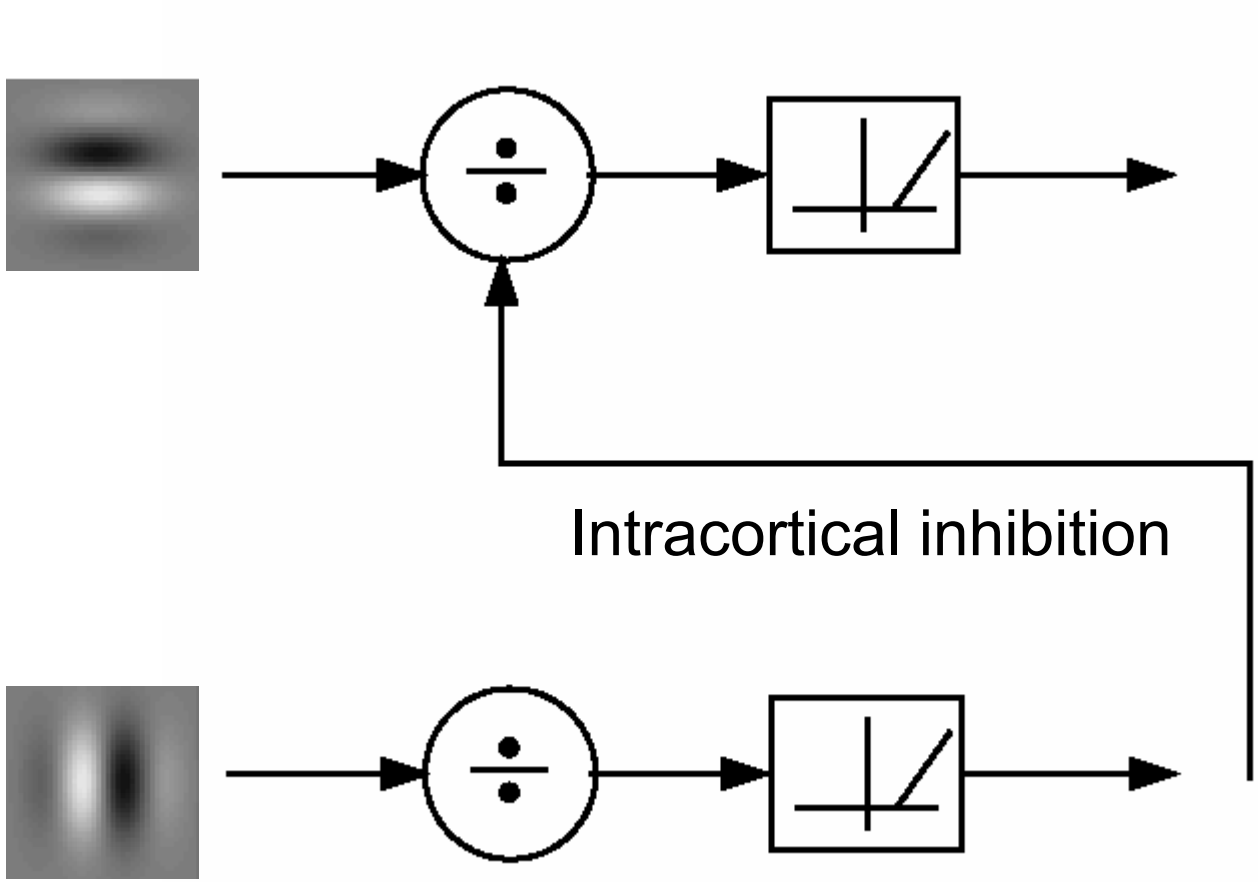
Blakemore & Tobin (1972)

Freeman, Durand, Kiper & Carandini (2002)

Classical explanation: Intracortical inhibition

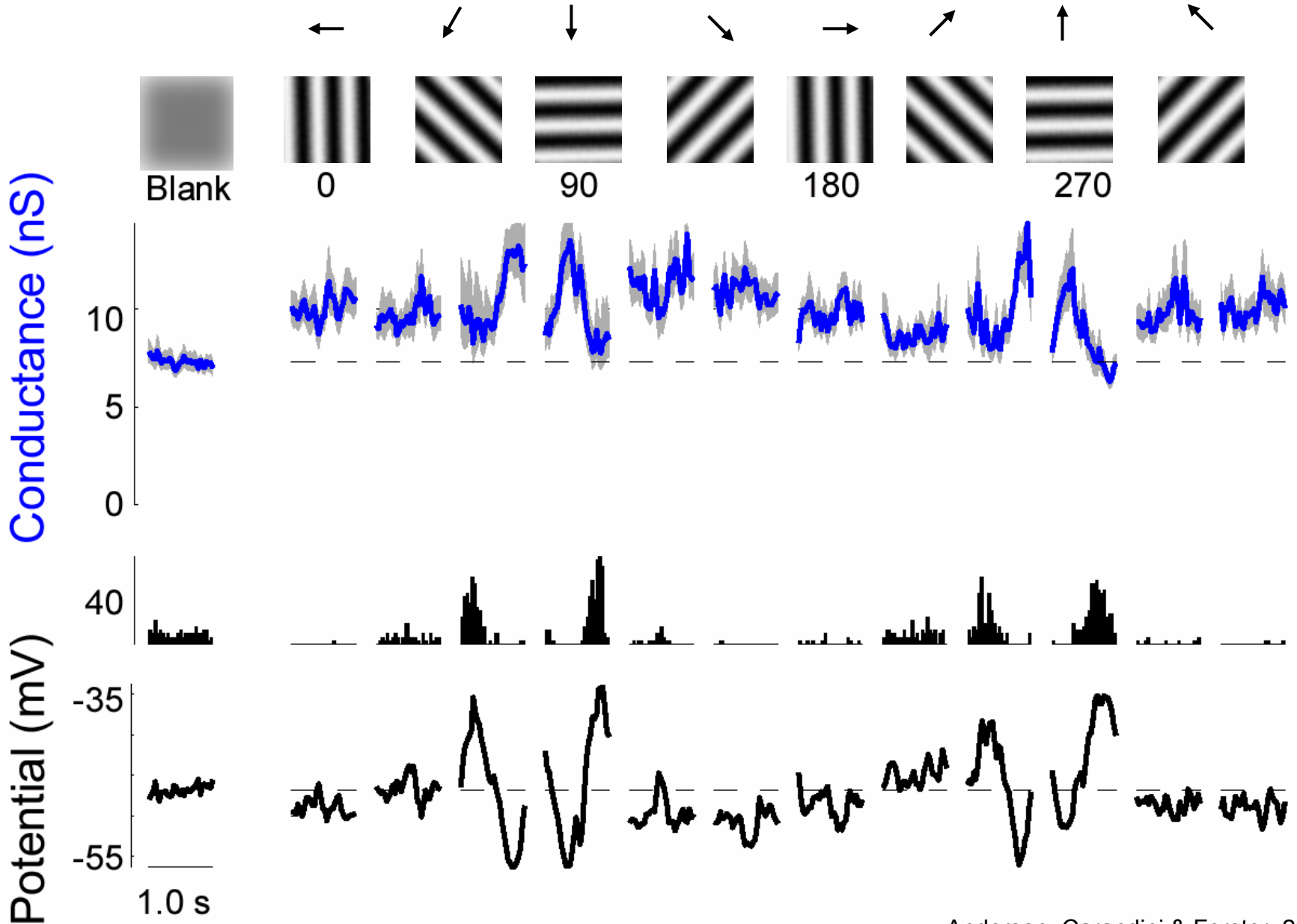


Divisive model



Heeger (1992)
Carandini, Heeger & Movshon (1997)

No evidence for cross-orientation inhibition

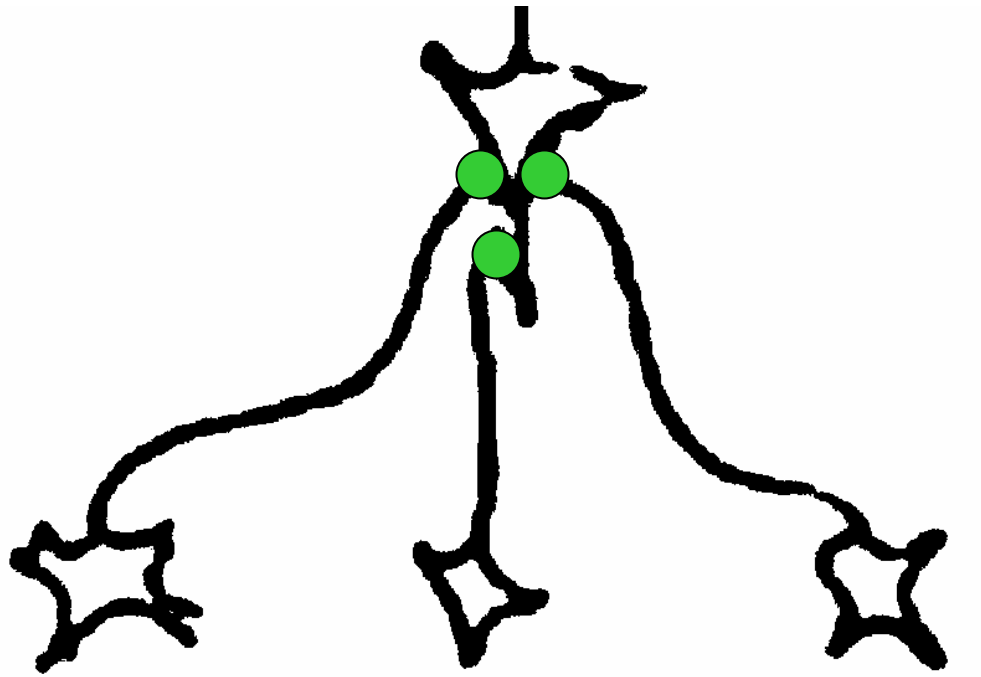


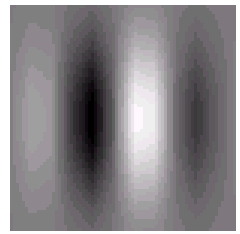
Anderson, Carandini & Ferster, 2000

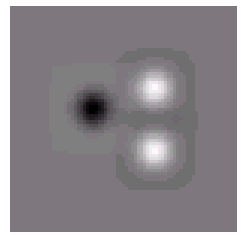
Model of V1 simple cell with depression

V1

LGN

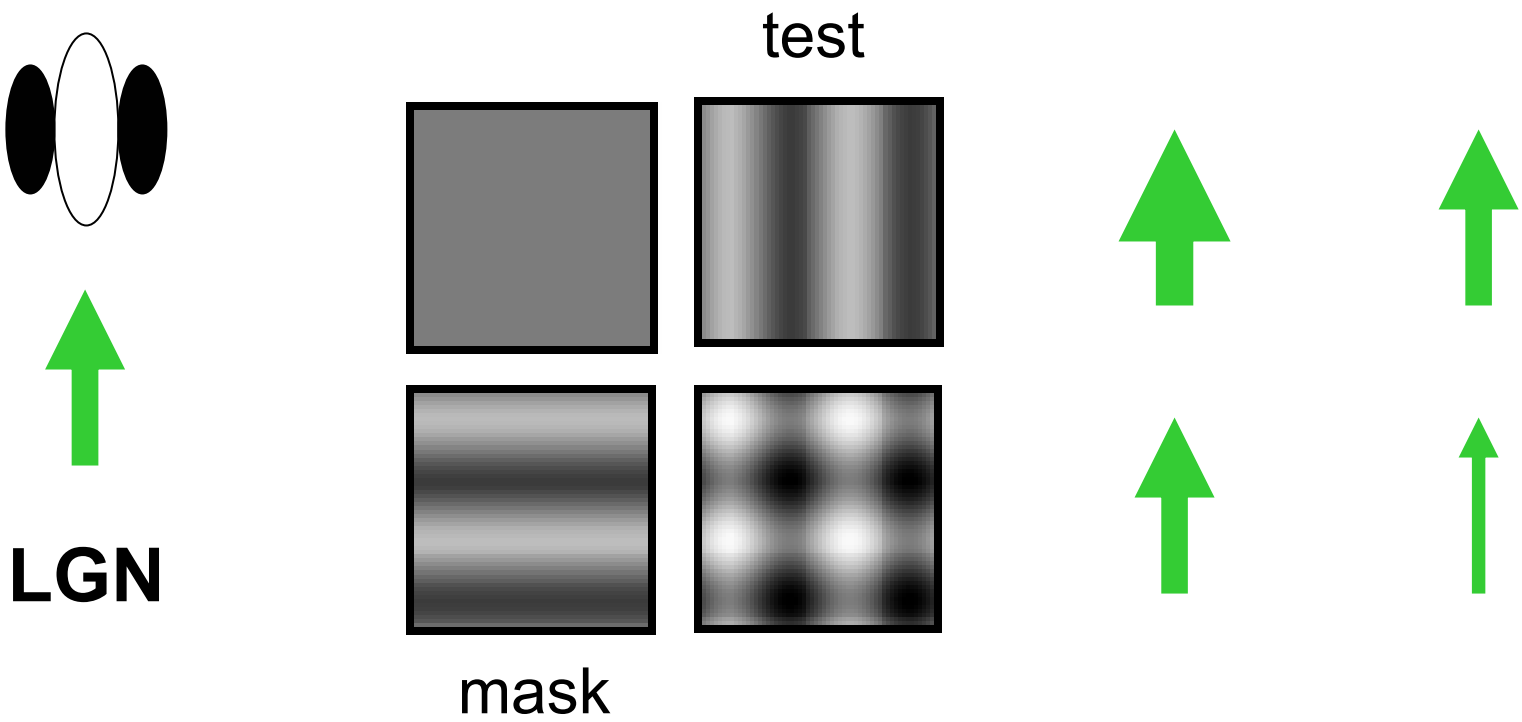






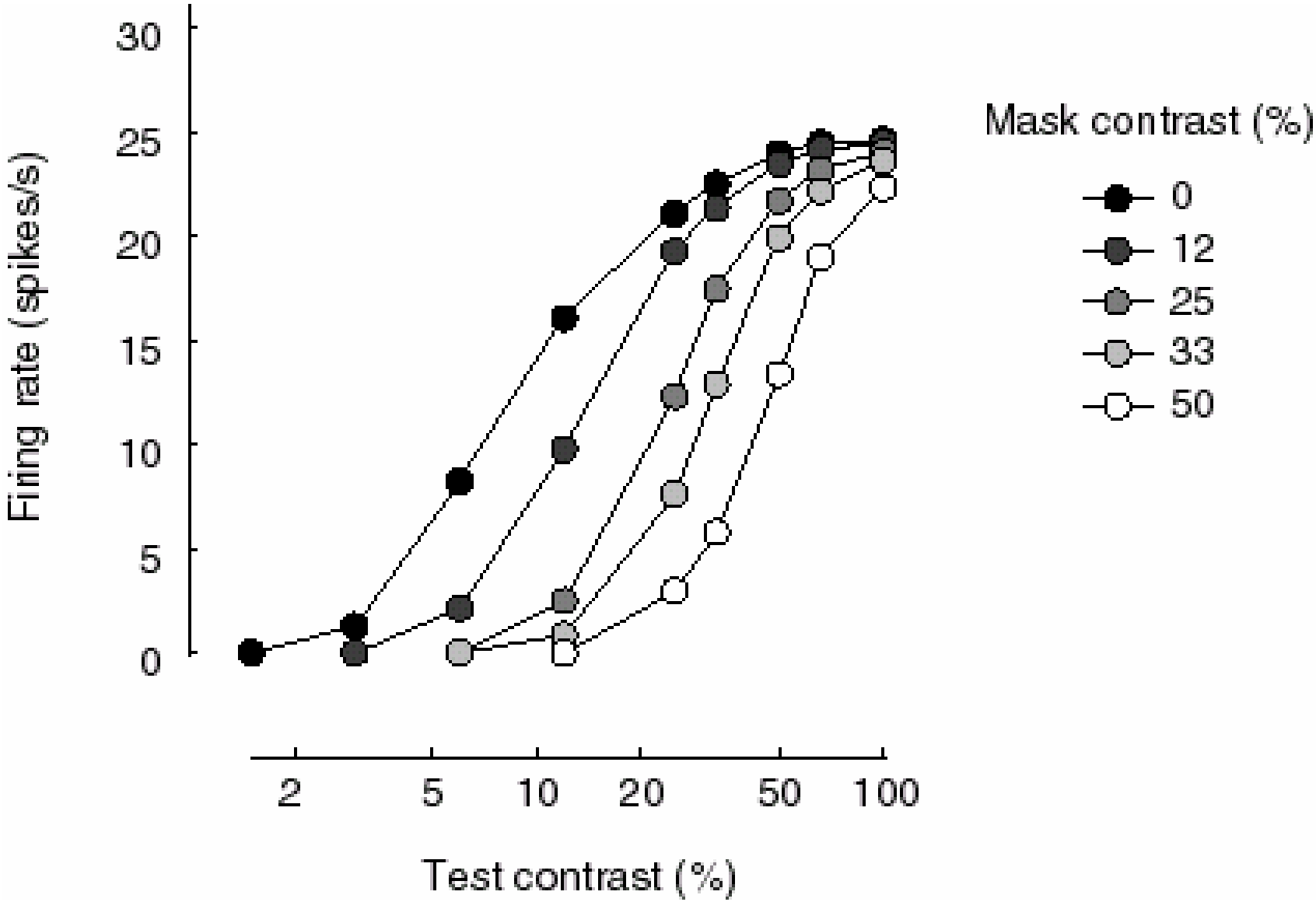
Hubel & Wiesel, 1962

New explanation: Synaptic depression



Carandini, Heeger & Senn, 2002

Suppression in model is divisive

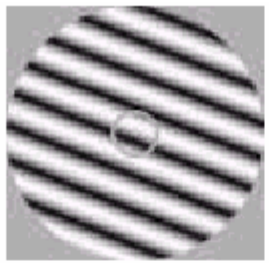


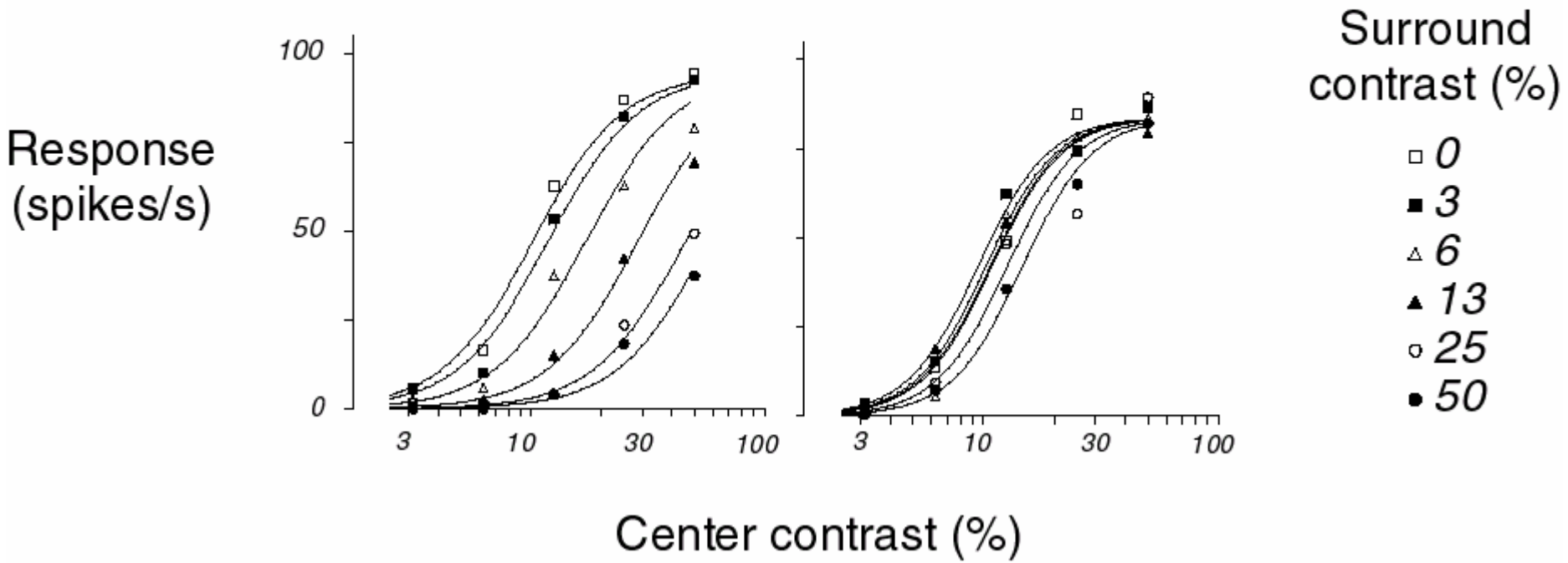
Carandini, Heeger & Senn, 2002

Alas

Had to stop here, time was running out…

Selectivity of surround suppression

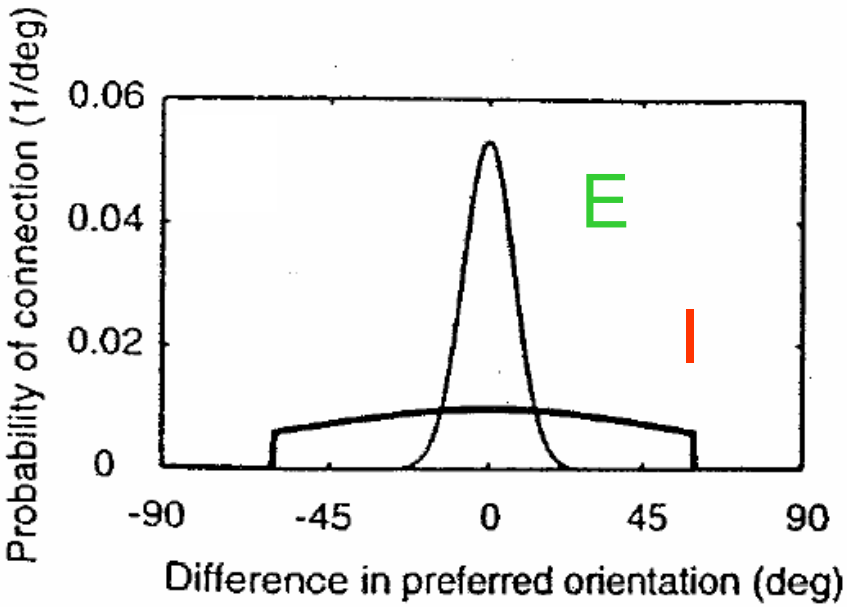


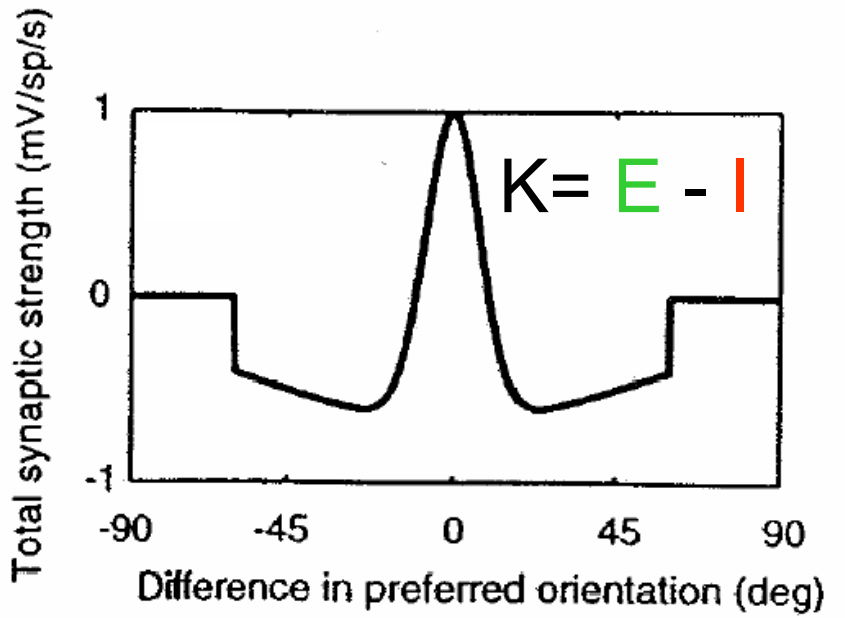


Blakemore & Tobin (1972)

Cavanaugh, Blair & Movshon (1997)

Selectivity: feedback models



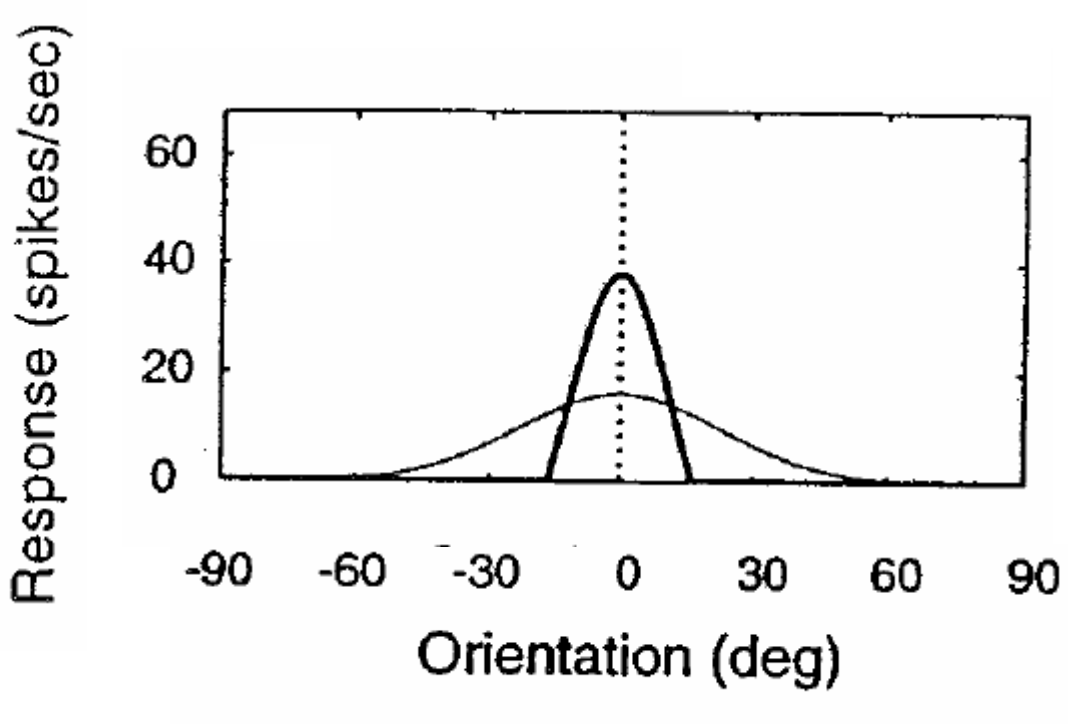


$$V(\theta) = V_{LGN}(\theta) + [K * R](\theta)$$
$$R = \max(V,0)$$

Ben-Yishai, Lev Bar Or & Sompolinsky (1995)
Somers, Nelson & Sur (1995)

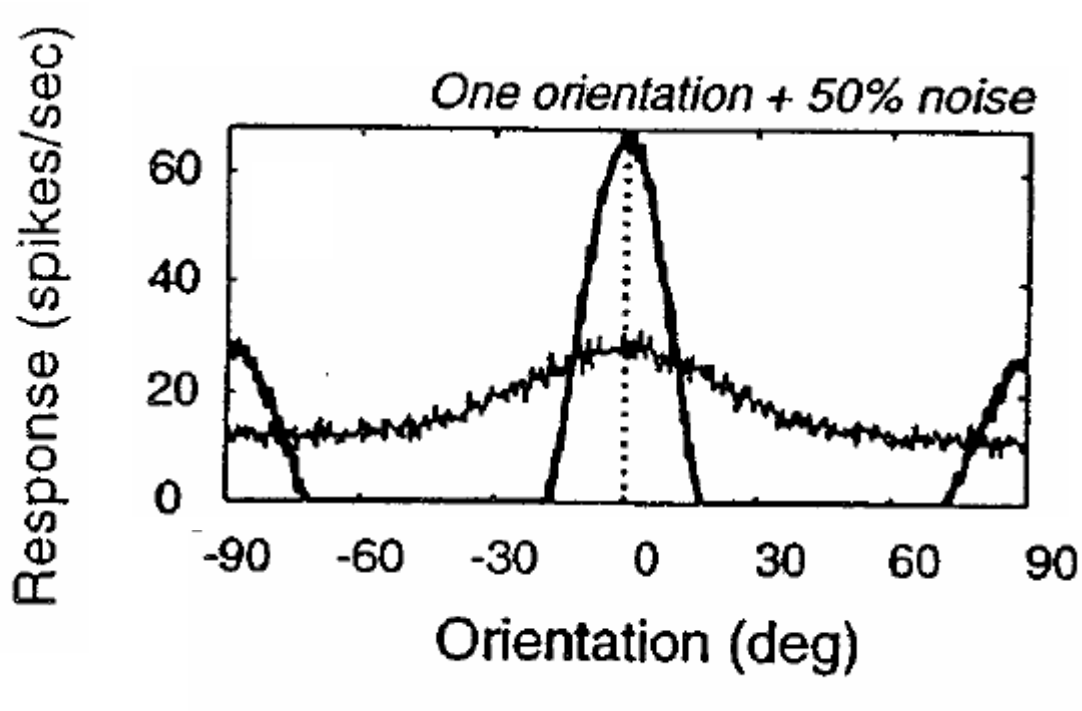
Carandini & Ringach, 1997

Feedback sharpens orientation selectivity



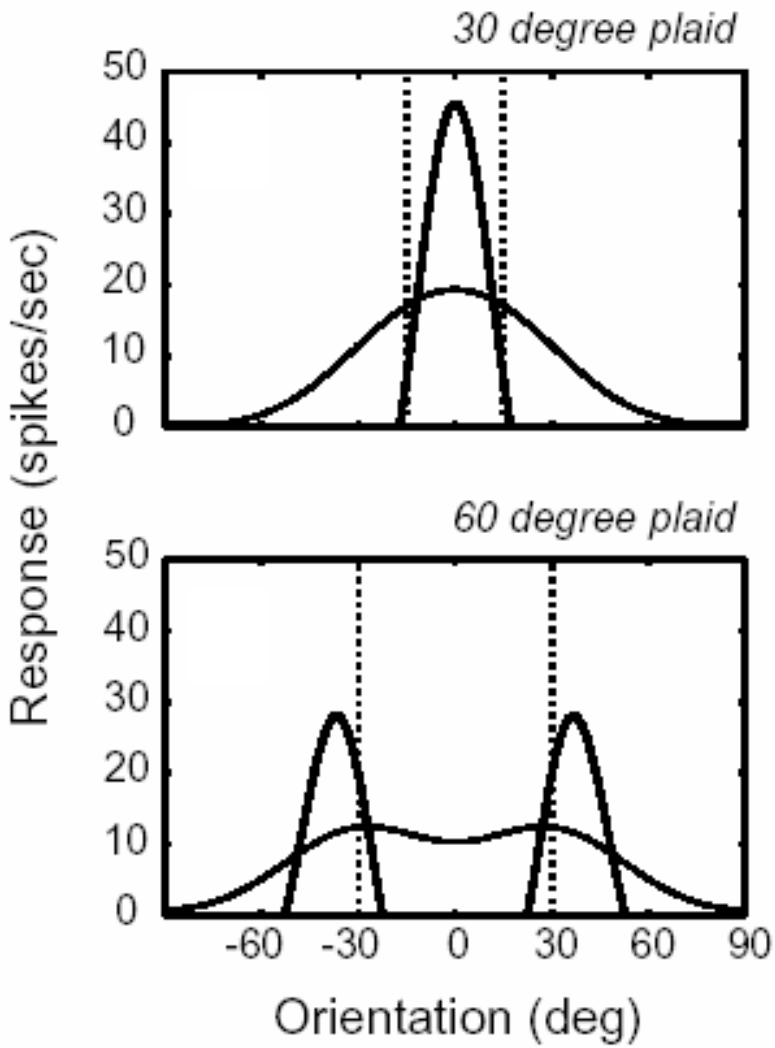
Carandini & Ringach (1997)

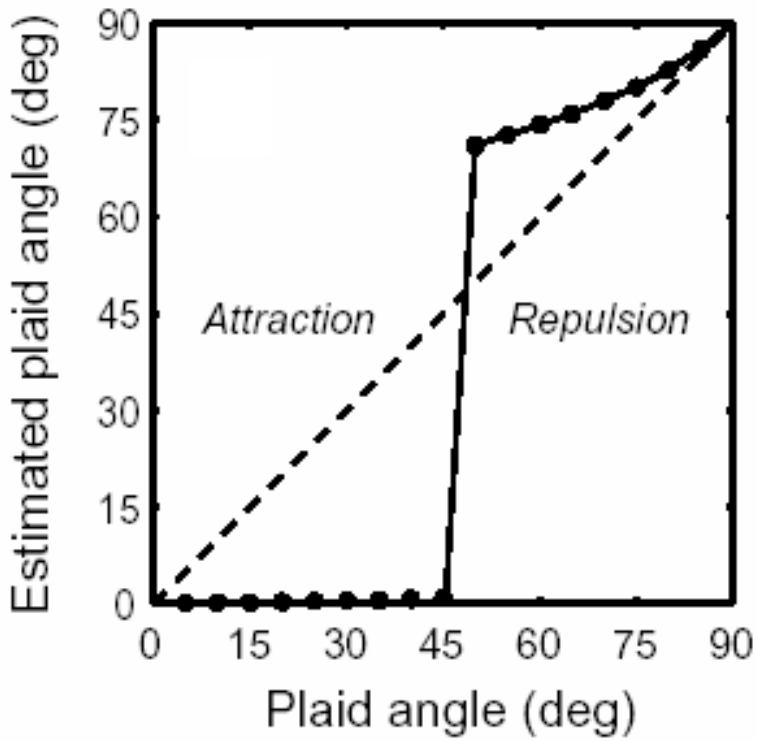
Feedback can give hallucinations



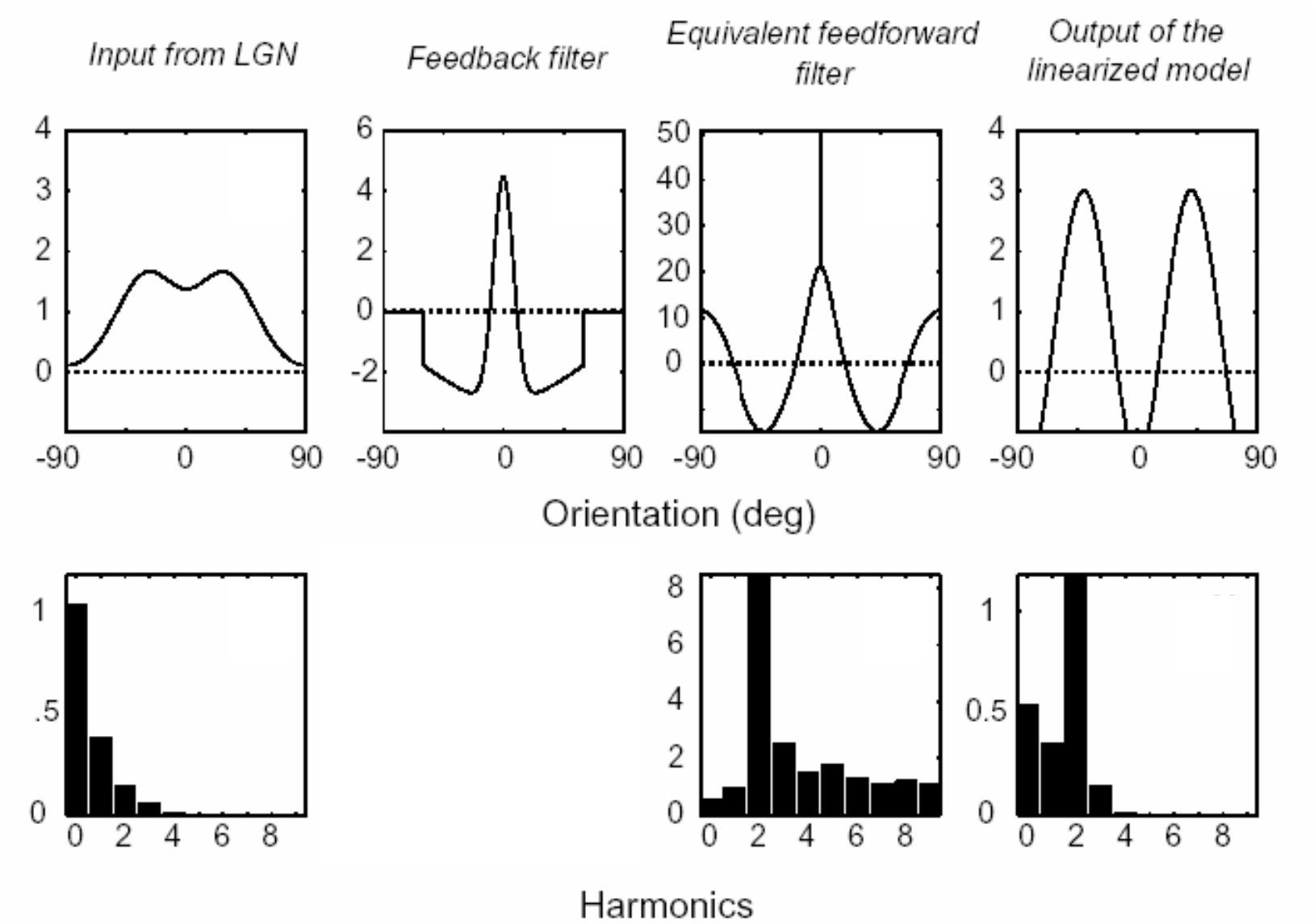
Carandini & Ringach (1997)

Feedback causes attraction/repulsion





Why the model favors orthogonal stimuli

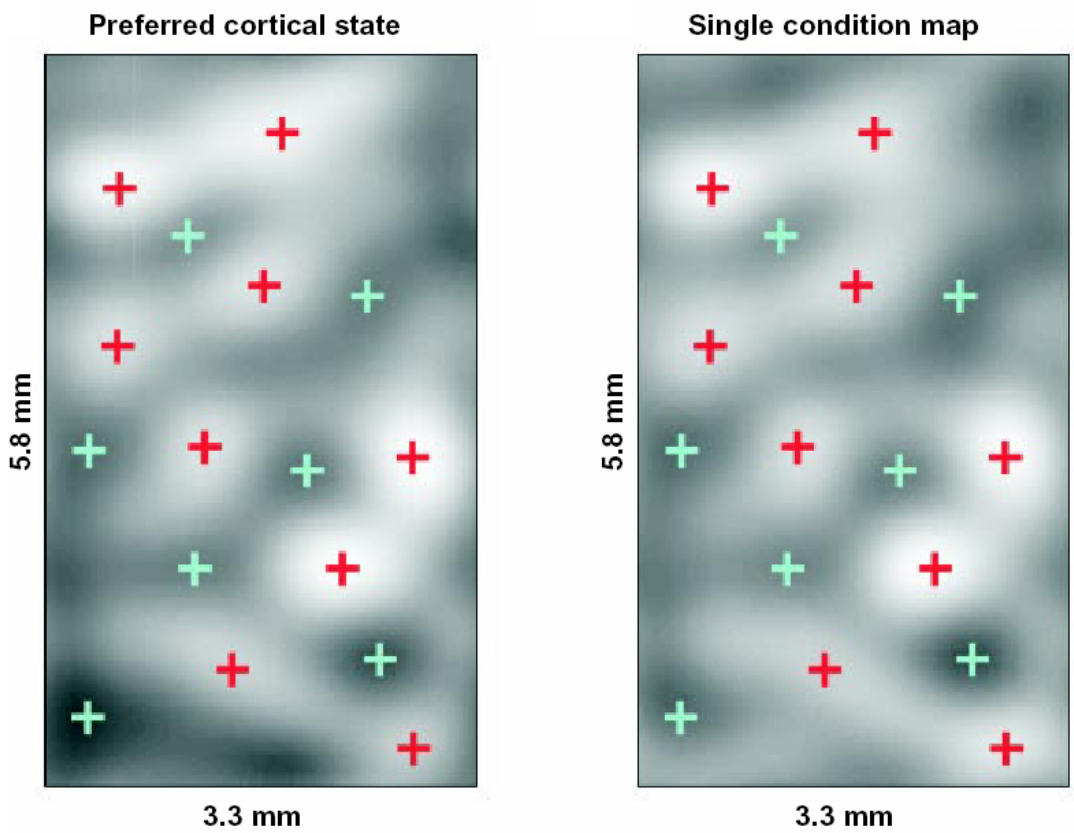


Cortical states

Preferred map of a neuron

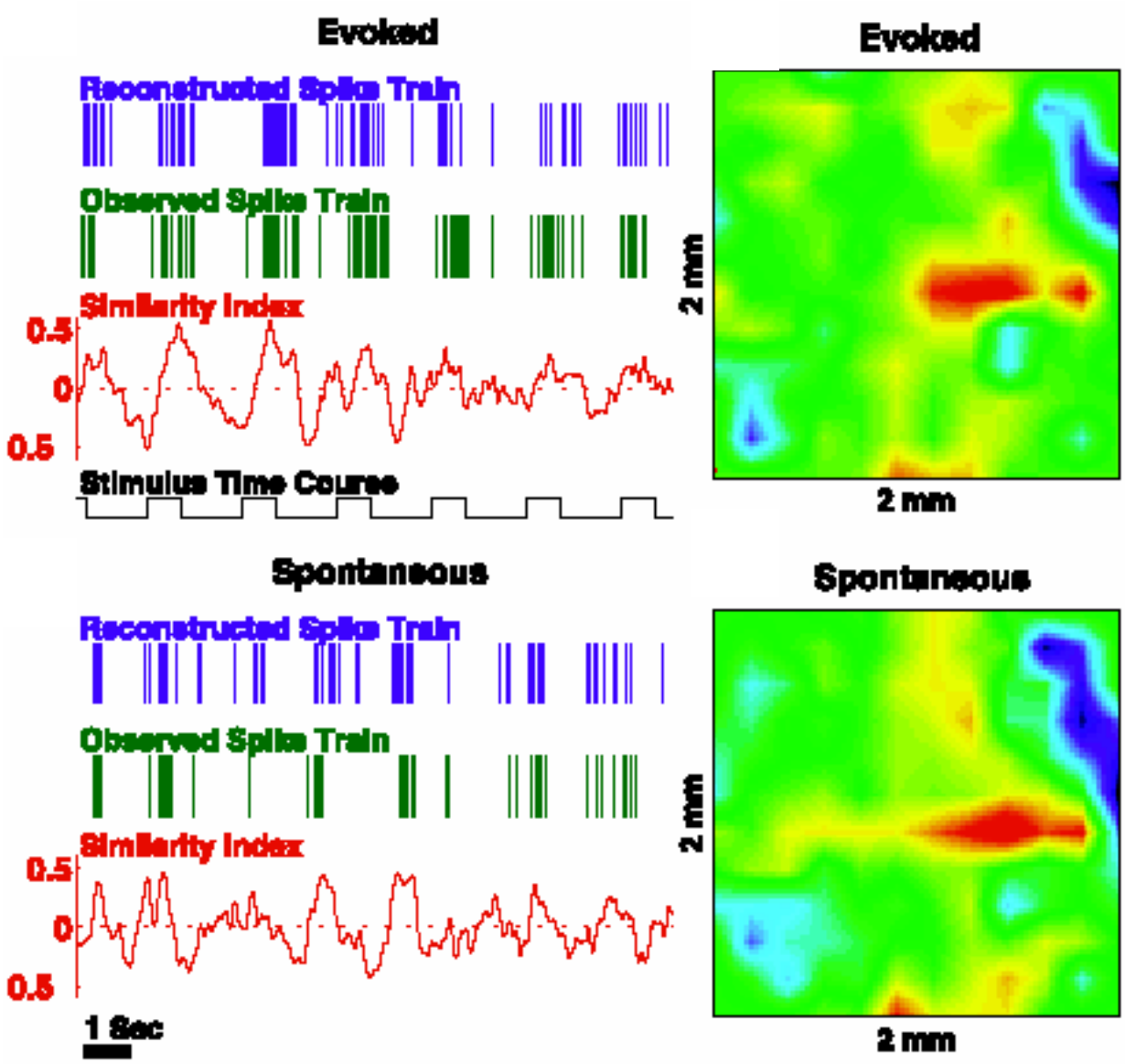
Spike-triggered map

Response to
preferred orientation



Tsodyks, Kenet, Grinvald & Arieli, 1999

Spontaneous preferred maps



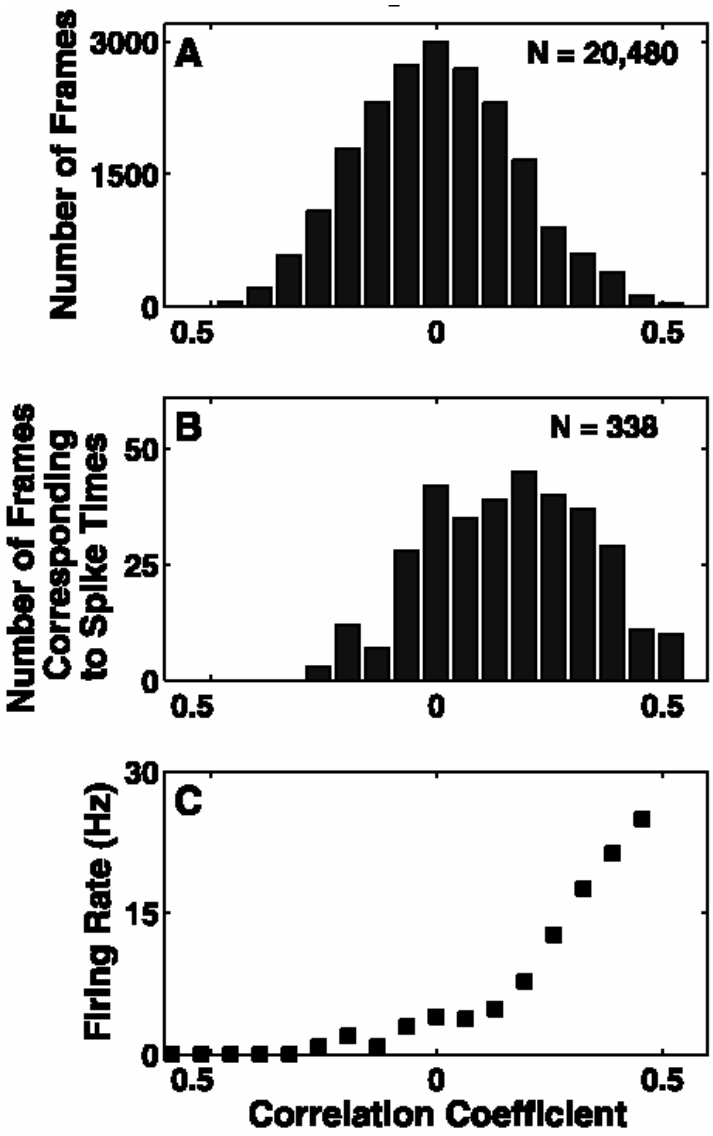
Tsodyks, Kenet, Grinvald & Arieli, 1999

Map-driven spiking

P(cc)

P(spike & cc)

P(spike | cc) =
P(spike & cc) / P(cc)



Tsodyks, Kenet, Grinvald & Arieli, 1999

Summary

- V1 neurons as linear filters
- Predicting responses to a moving stimulus
- Nonlinear properties, divisive model
- Possible physiological substrates
- Wiring: Feedback models
- Evidence in favor of / against feedback
- Endogenous activity, cortical states