Multiple Zones of Contextual Surround for V1 Receptive Fields

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Talk outline

- A V1 model to study contextual influences.

- How contextual influences affect responses to a grating patch.

- Dependence on size of grating — summation zone, suppression zone, (Sceniak et al 1999), and, additionally, the second rise, and more.

- Relation with figure-ground effects, and visual behavior/computation.

The V1 model and its function

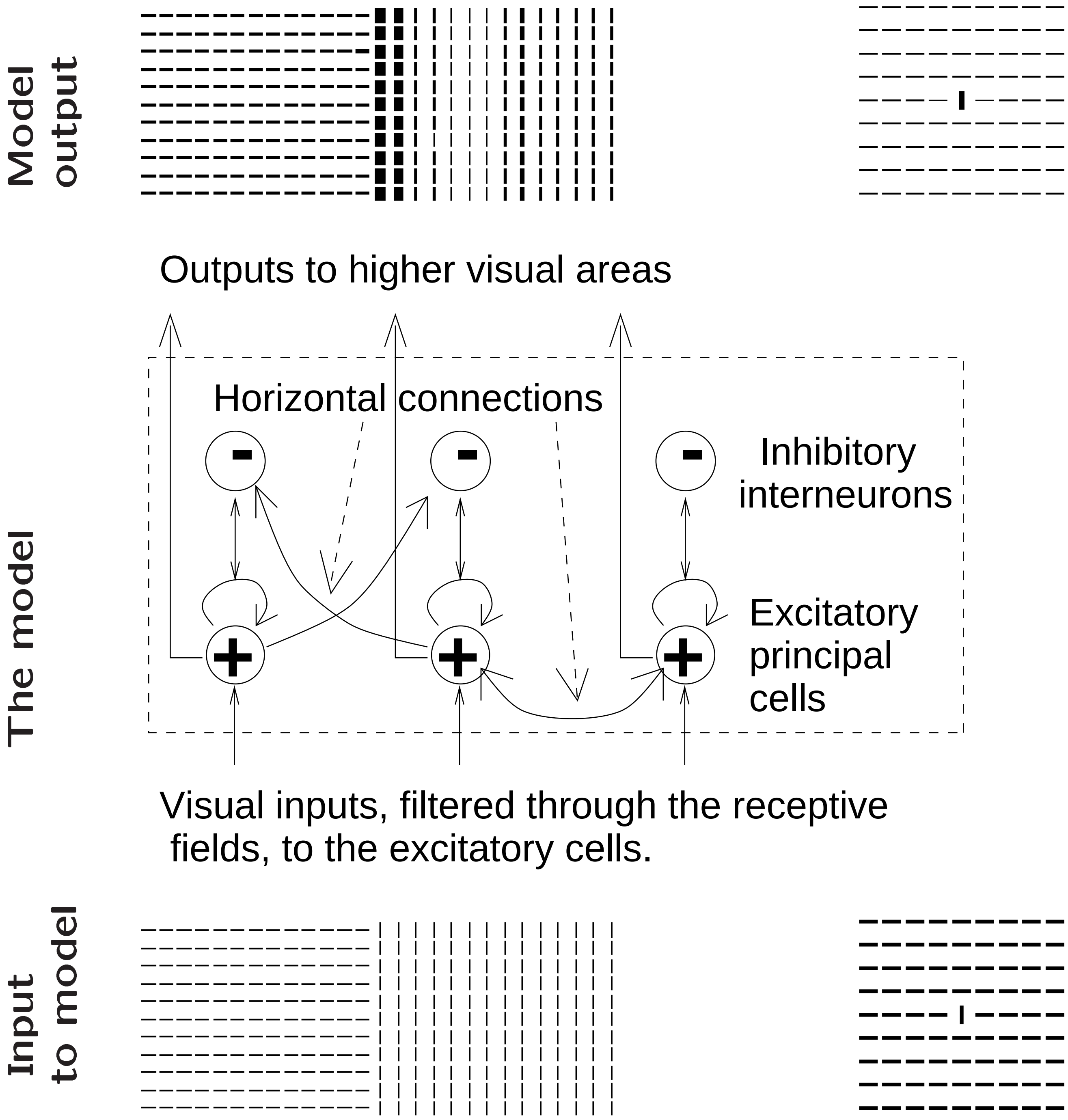
Input: bar's contrast

Output depends on

(1) the bar's contrast;

(2) the bar's context;

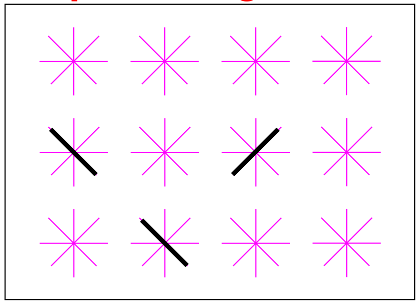
highlighting where homogeneity breaks down



Model Schematic:

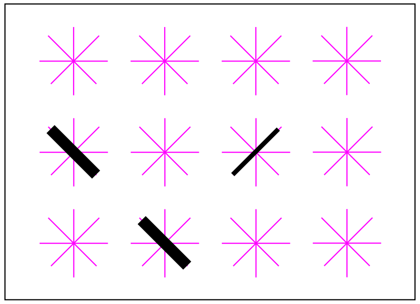
Units representing the edges are excited. Units representing edges form a network

Sampled image in cortex

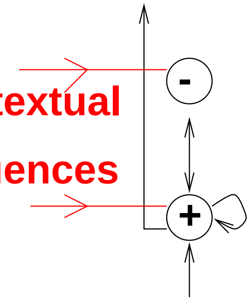


Intra-cortical Interactions

Computed image in cortex after cortical interactions

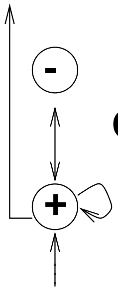


contextual influences

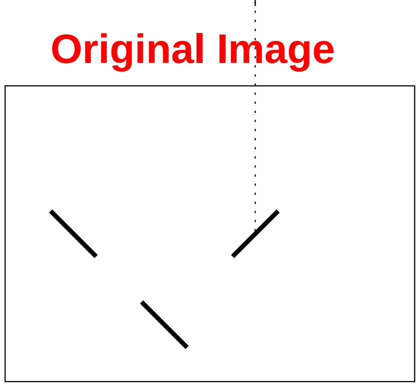


Sampled by edge detectors finding 3 edges at different locations i, j, k, and orientations $\theta_i \ \theta_j \ \theta_k$

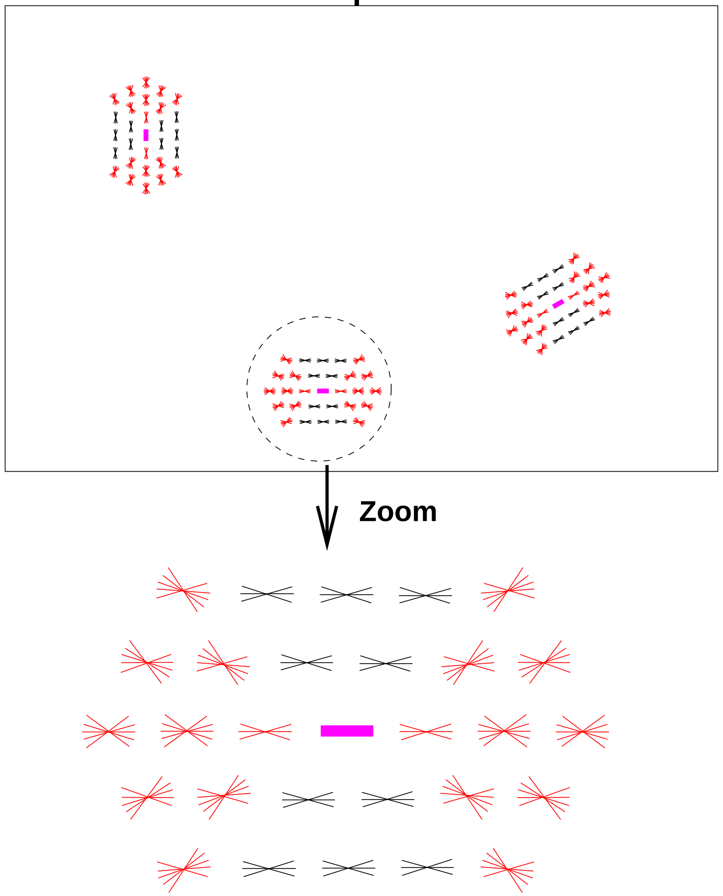
One edge detector



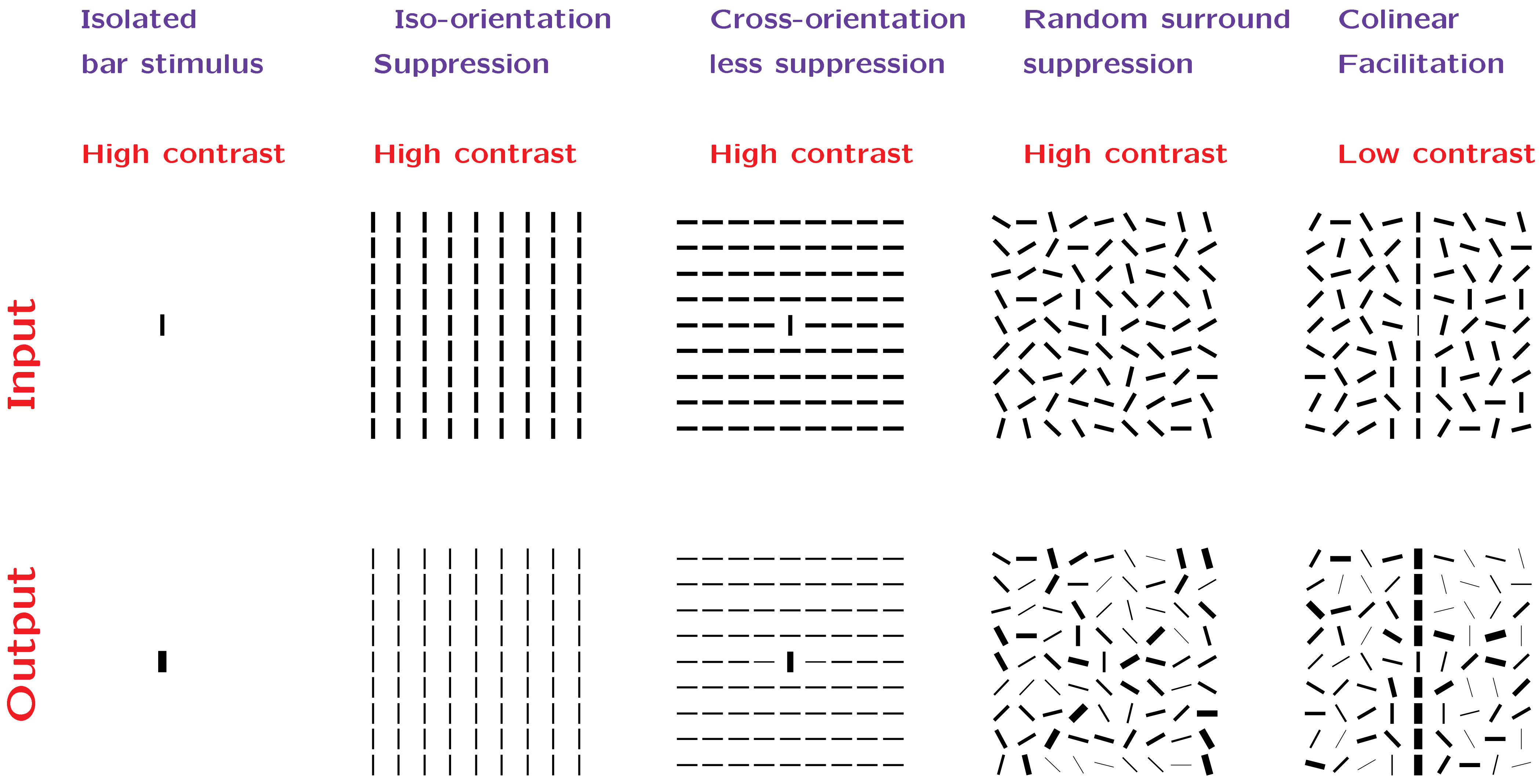
Original Image



Interaction pattern



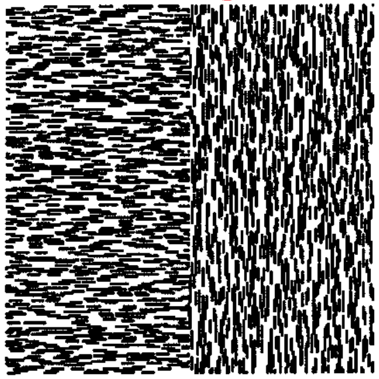
Model produces the usual contextual influences observed in V1



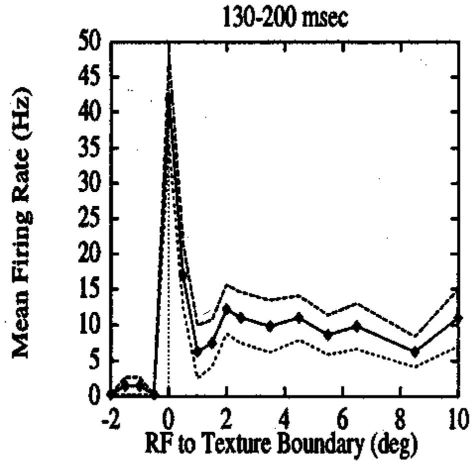
Another product of contextual influences:
The border effect, physiologically and in the model

Physiology

Visual stimuli



Cell responses

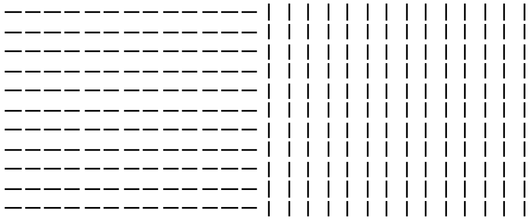


data from Lee et al. 1998

Also observed by Gallant et al. 1995

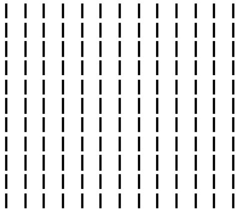
Model

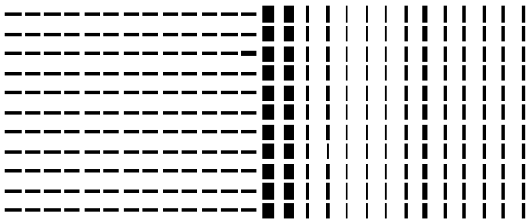
border between two textures



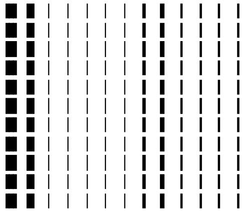
border between
a texture and a blank

Input
blank
here





Output
blank
here



Note: **The border region**

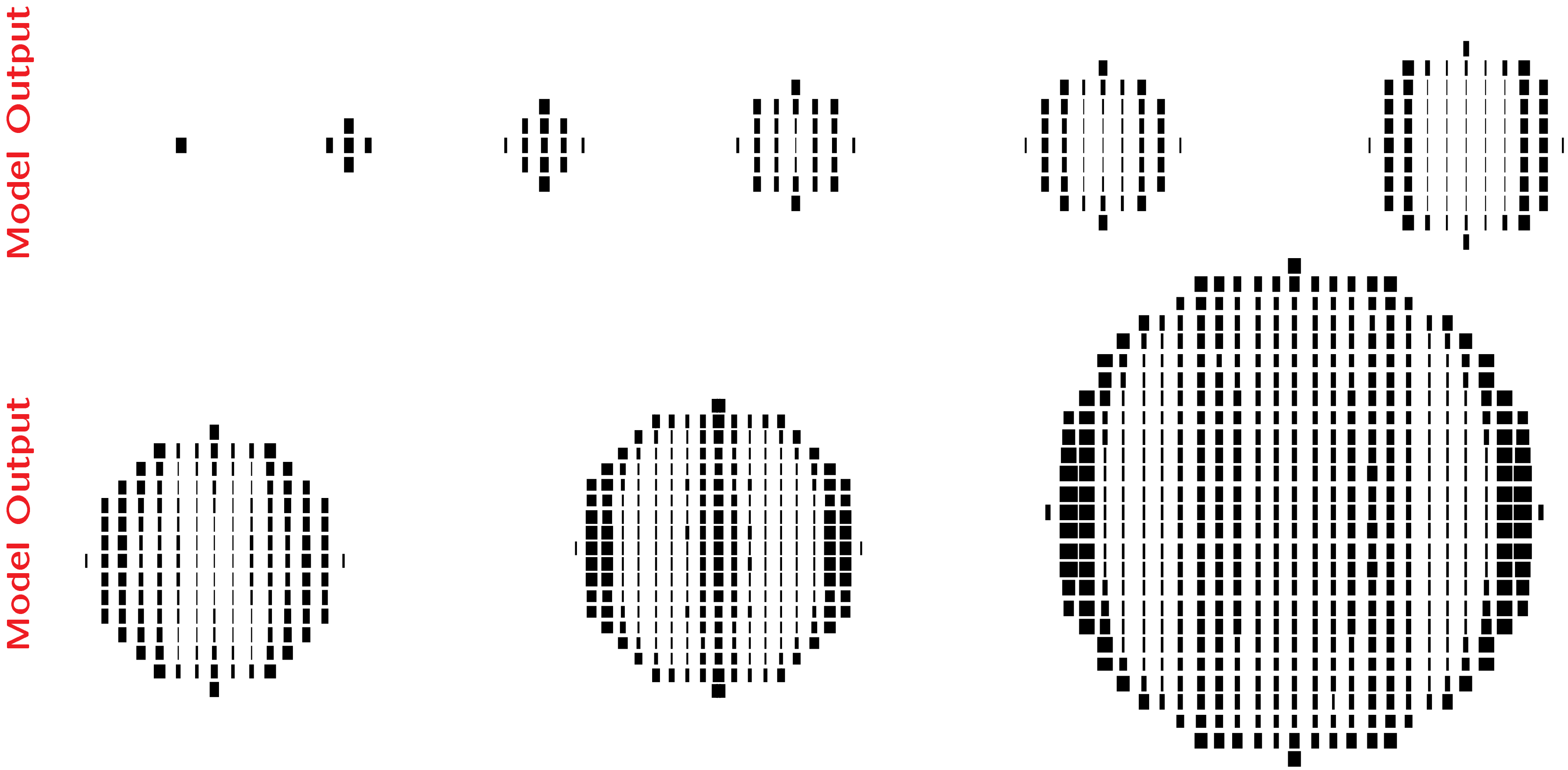
The border suppression region

The secondary ripple.

What then should be the

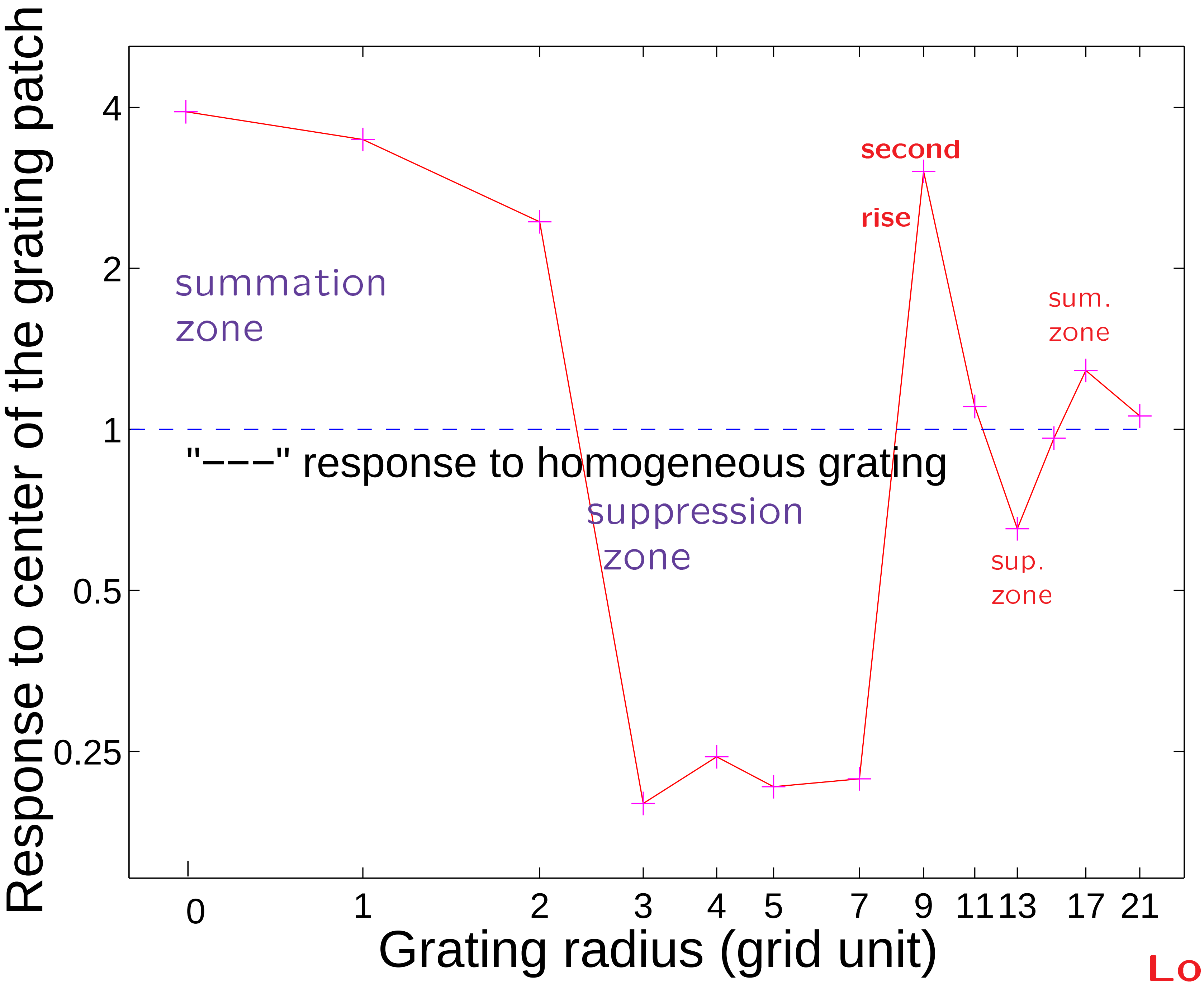
Responses to a grating patch ? (cf. Sceniak et al 1999)

Direct input field vs Receptive field



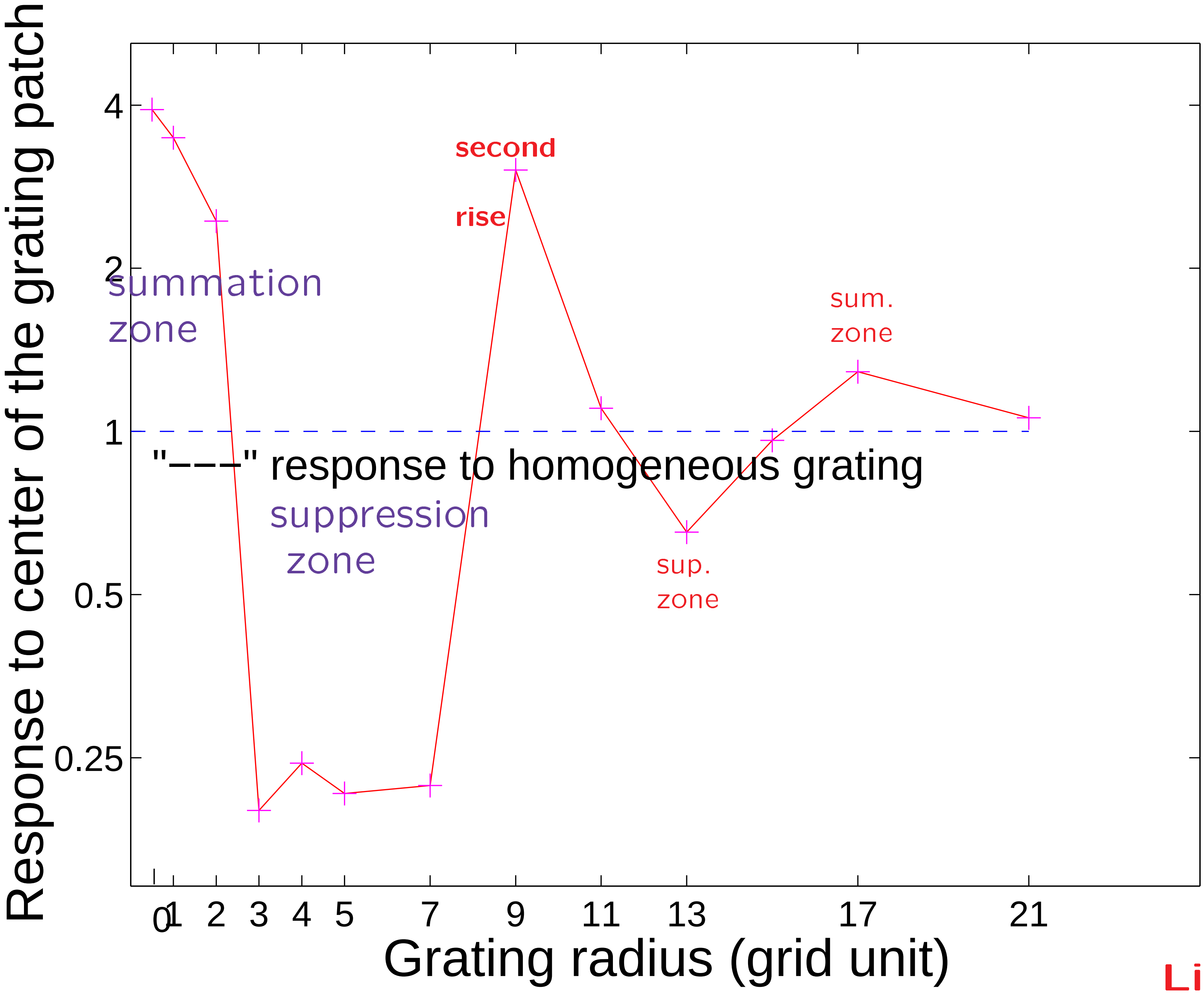
As the grating patch increases, the response increases, decreases, and then, at an even larger grating size, **a second rise.**

Summation zone/suppression zone, second rise?.



Log size scale

Summation zone/suppression zone, second rise?.



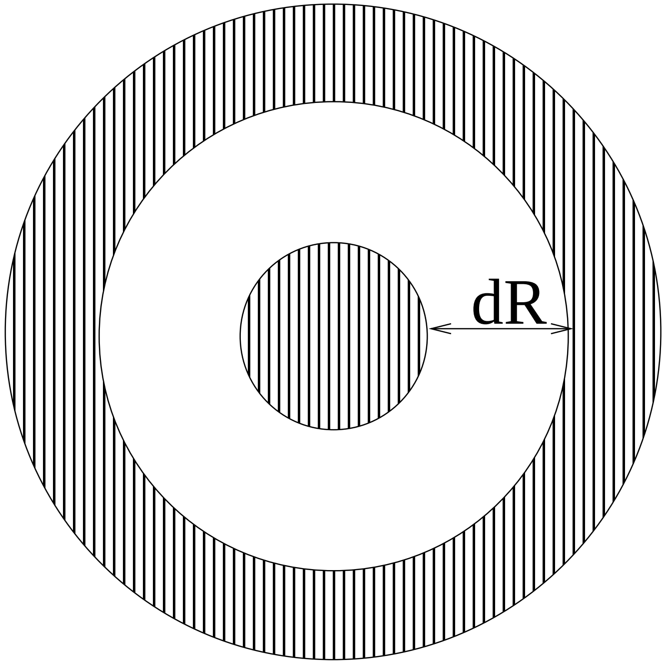
(Sillito lab observed some indications of the second rise)

Linear size scale

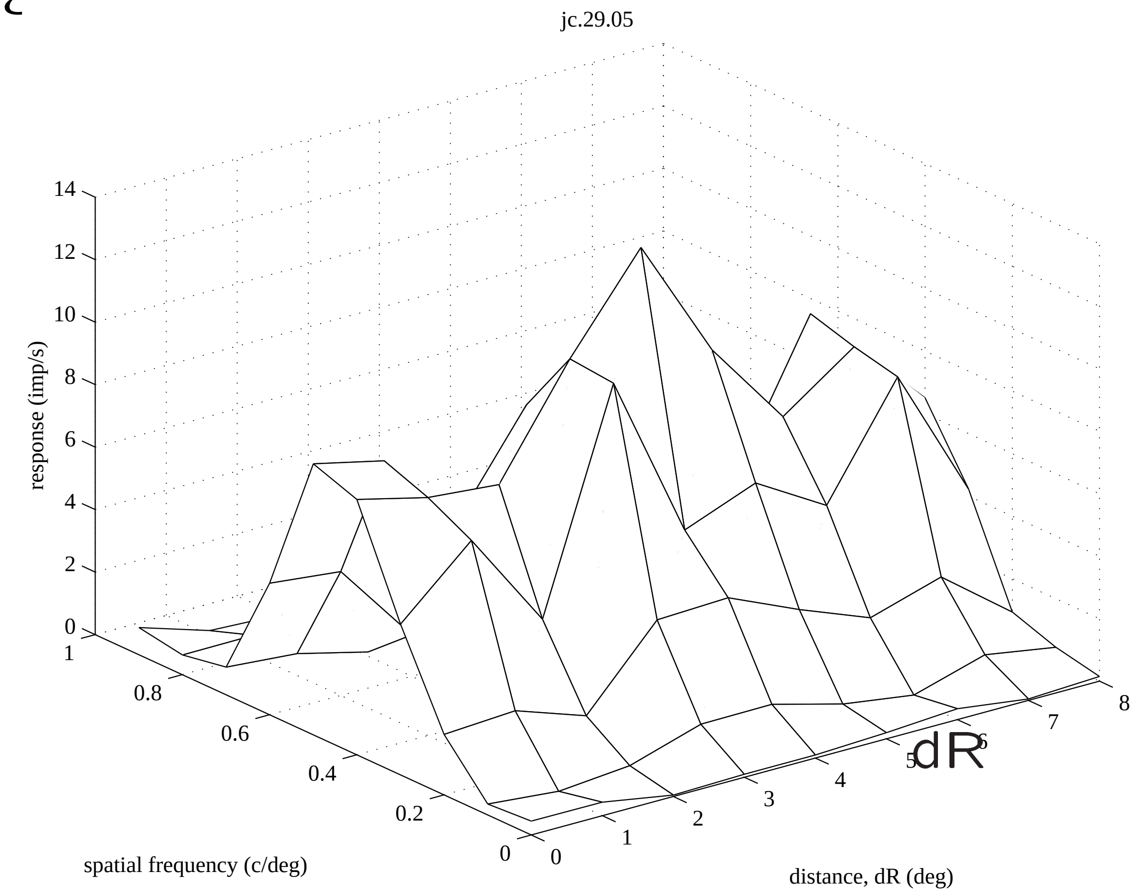
The second rise predicted can be tested easily physiologicallyy.

There is an indirect physiological evidence
(courtesy of A.B. Bonds and J. Kabara, 2000):

Stimuli: center grating,
and a ring of outer grating.



Response to center vs. dR, etc.



What if the grating patch is surrounded by an orthogonal background grating?

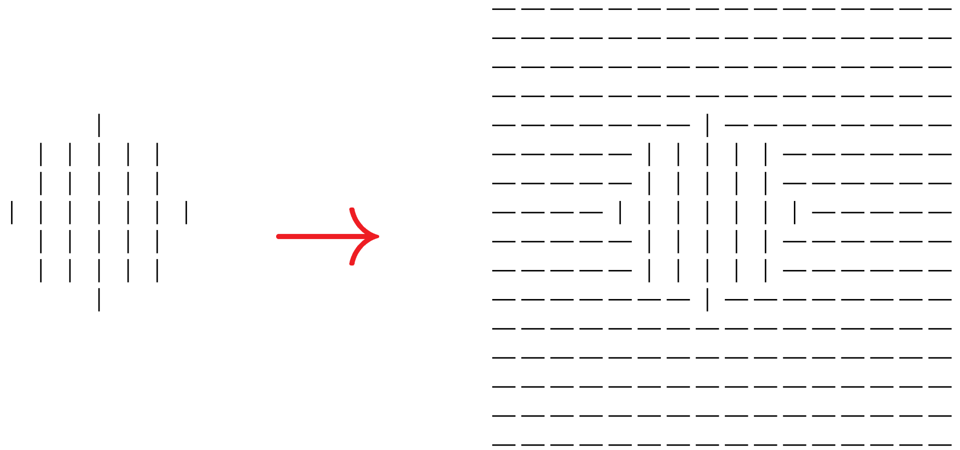


figure-ground

Usually, the general contextual suppression from the background grating reduces the responses to the center grating.

When the size of the figure grating is such that the center of the figure grating is in the border suppression region, suppression from background on the border of the figure grating disinhibits the figure center.

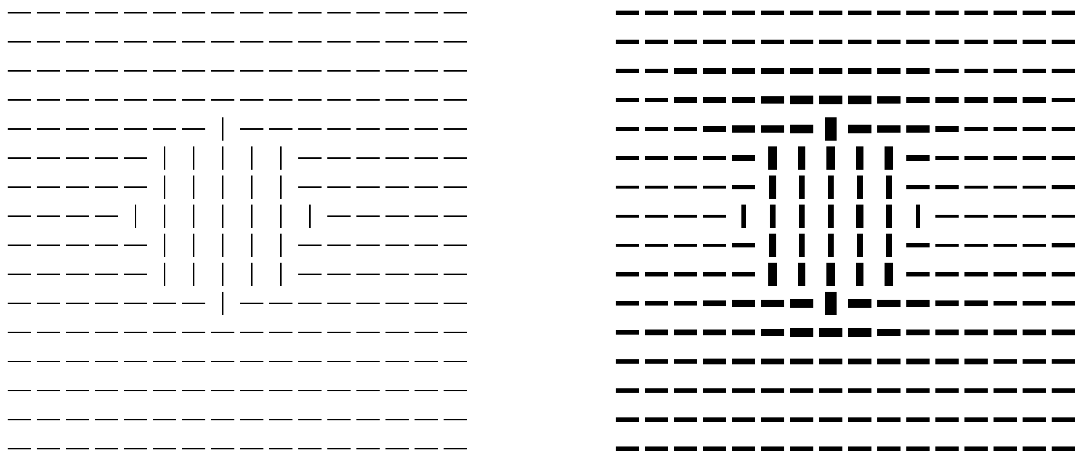
Cross-orientation facilitation observed by Sillito et al

happens when the figure center is in the border suppression region

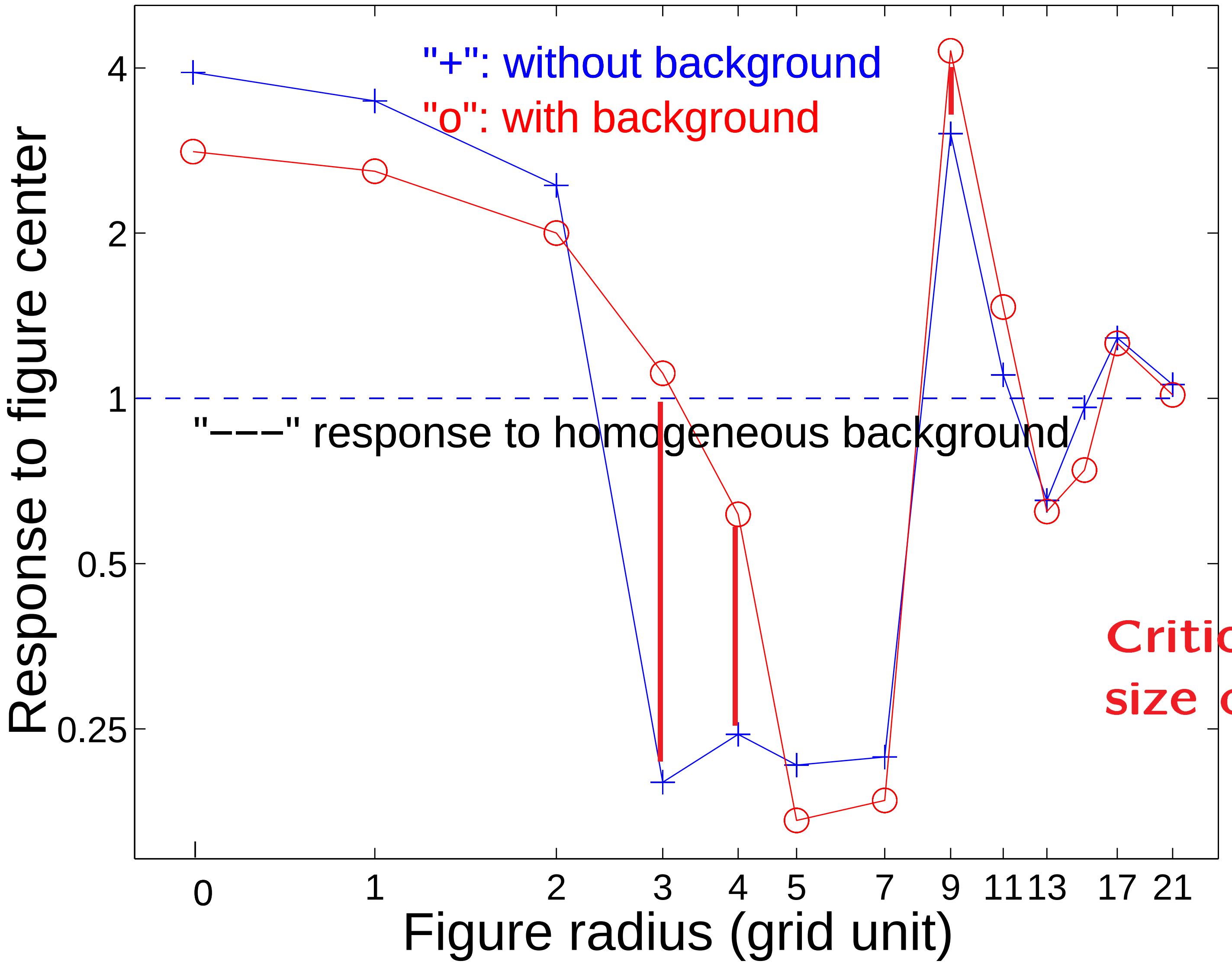
Model Input Model Output

The figure center is at the border suppression region

The center of figure is dis-inhibited by the background grating, which suppresses the figure border via general orientation unspecific suppression



Cross-orientation facilitation — dependence on the figure size

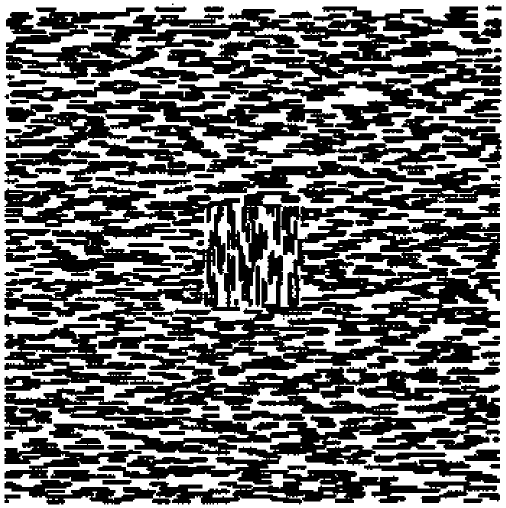


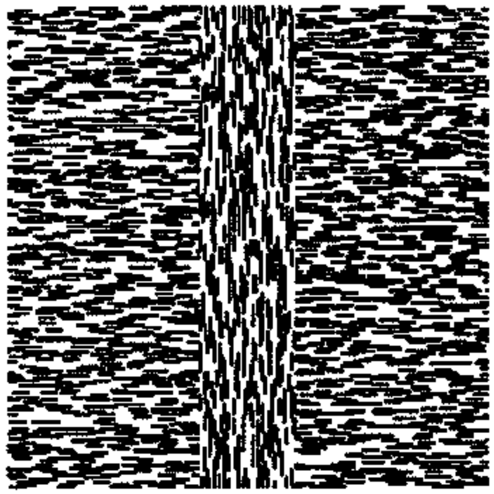
Critical exp. parameter: size of figure grating

Explains why some did not observe this phenomena

“Figure-ground effects”, ”medial axis effects” observed physiologically

Visual stimuli

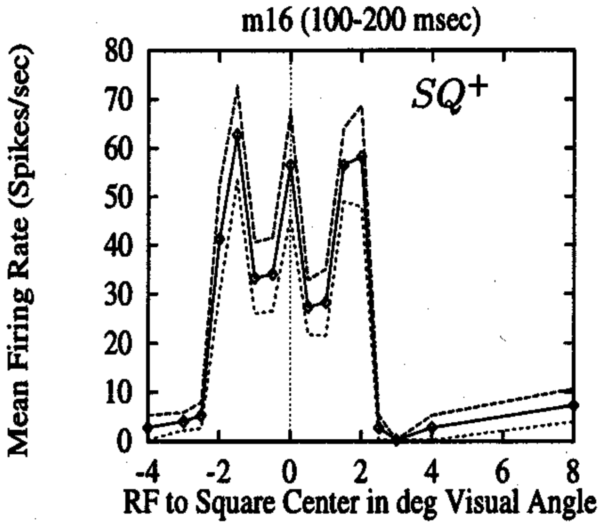


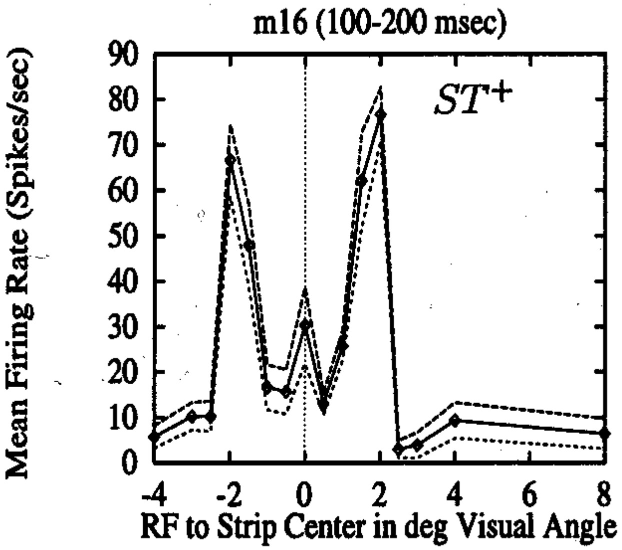


Higher responses to figure,
its medial axis,
than responses to grounds,

observed by
Lamme, Zipser, Lee, etc.

Cell responses





What can our model
say about them?

data from Lee, Mumford, Romero, Lamme 1998

Model Input   Model Output

When the figure is the border region itself
The whole figure highlights, Observed by Lamme, Zipser, et al

When the figure center is at the border suppression region
The figure center suppressed

When the secondary ripples from both borders reinforce
The medial axis effect Observed by Lee et al 1998

When the figure is large enough
Figure ground effect diminish in figure center

Prediction:

"The figure ground effects"

(like those observed so far in V1)

(1) depend on the figure size,

(2) disappear for large figures,

(3) are caused by the border effect.

(4) could be accounted for by V1 mechanisms

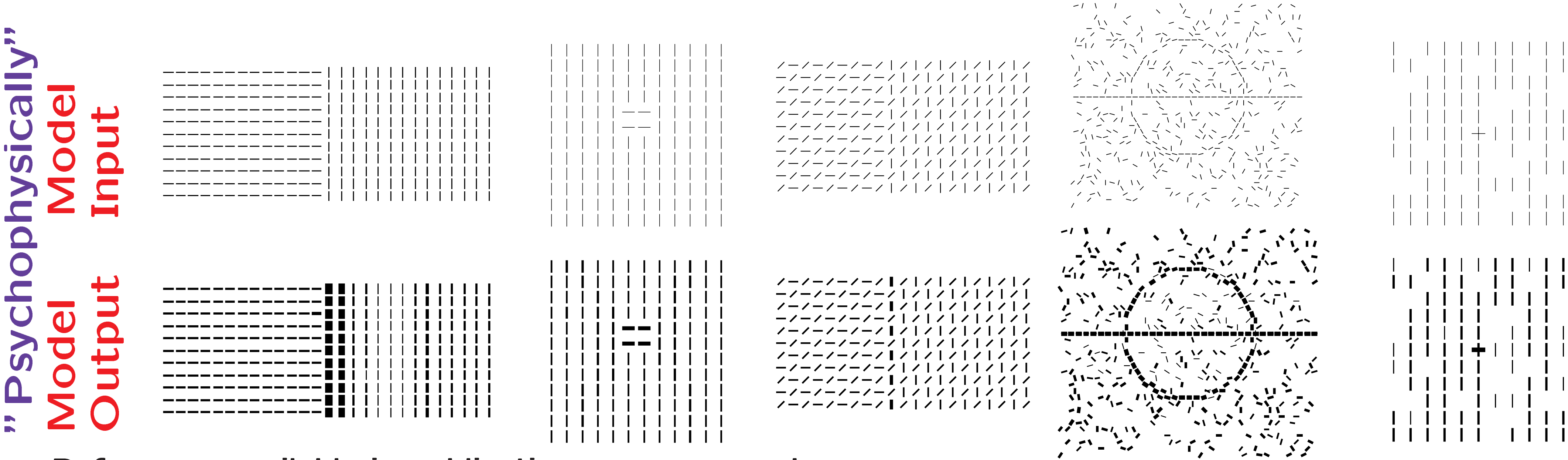
(without resorting to feedback

from higher visual centers)

Computational goal of contextual influences

Not simply to complicate the “receptive fields”.

Proposal: **But to achieve pre-attentive segmentation or visual grouping (pop out), e.g., texture segmentation, contour integration, figure search among distractors. Achieve global visual computation from local “classical receptive fields” and finite range intra-cortical interactions**



References available in publications or on my webpage

Summary

Contextual influences could give more than a single summation and suppression zone to the “receptive field”.

Prediction: Multiple summation and suppression zones may exist beyond the inner zones.

Relates to other contextual effects: cross-orientation facilitation, figure-ground effects, with **testable predictions**.

Finite range contextual influences provide neural basis for global visual computation: pre-attentive segmentation and grouping.