Week 7: Parallel visual pathways and perceptual organization

1) Neon color spreading
2) How thin is “thin”?
3) Spatial and orientational competition
4) Hyperacuity
5) Cooperative-Competitive (CC) Loop
6) Bipole cells, then and now
7) von der Heydt, Peterhans, & Baumgartner, 1984 and other physiology/anatomy
8) Spatial impenetrability

INTRO TO NEON COLOR SPREADING

What is so special about neon color spreading that earned it mention in the title of an early report on the BCS/FCS theory -- at a time when neon was “not on the radar” among psychophysicists?

You would never arrive at BCS/FCS complementarity if you only considered “1-D” phenomena!

WHY BOUNDARY AND FEATURE CONTOURS

The distinction of boundary contours* and feature contours* is counterintuitive, because:

“Real” luminance steps always generate both, and

Boundary contours and feature contours are generally perfectly aligned in perceptual space; those originating directly from luminance steps certainly are.

Information from the two contour signals usually gets “put back together” in a way that makes it hard to suspect that it was ever split up.

* What, in general, is a contour?

Cf. FIRE* theory of G, 1983, where boundaries and features are coded in the same signal.

Note that most current schemes in machine vision for anisotropic diffusion (a.k.a. inhomogeneous diffusion, geometry-based diffusion, conductance-based diffusion) also diffuse the very signal whose gradient is used to gate the diffusion.

* The record shows that Grossberg has on occasion criticized (retracted) his own model! How this was done for FIRE vs. BCS/FCS merits some attention.
Recalling that the locus of original (i.e. image-contrast-driven) BCS and FCS signals is, almost by definition, overlapping, ...the observed final configuration of effective BCS and FCS signals departs significantly from the original configuration.

Spatial interactions within and between BCS and FCS result in a final configuration that neither could achieve alone.

The resulting illusion is informative about BCS/FCS geometry and dynamics.

BCS/FCS theory explains how:

a red cross placed inside an Ehrenstein figure

produces color spreading.

“Real” contours of small cross cannot enclose red featural quality;

“Illusory” contours of Ehrenstein figure do!
**RELATIVE CONTRAST WITH BACKGROUND**

BCS's First Competitive Stage employs *shunting inhibition*. Inhibition of cells at (a) is balanced; at (b) cells of black edge are more active than those at red edge due to higher contrast with background.

**NOTE:** Strength of neon effect varies with *amount of contrast.*

(van Tuijl & de Weert, 1979; Redies & Spillmann, 1981)

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**TRAPPING THE ESCAPING COLOR**

The “same orientation, across position” inhibition combines with an “across orientation, same position” inhibition to generate *“end cuts”* -- enhancements to boundary signals perpendicular to line ends.

**“Disinhibition”** of perpendicular boundary signals (“*end cuts”*) occurs via the first and second competitive stages of BCS (1985).

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**EMERGENT BOUNDARY FORMATION**

The cooperative-competitive loop (CC Loop) combines long-range cooperation with short-range inhibition to choose coherent boundaries and suppress alternatives.

---

**STIMULUS CONDITIONS FOR NEON**

**LEARN TO DO THIS!**

Leaving aside Grossberg *et al.*'s modeling,

what *stimulus conditions* foster the *perceptual phenomenon* of neon color spreading?

What is the significance of “*thin*” lines for neon spreading in the Ehrenstein configuration? That is, does the phenomenon *require* thin inducers and thin “spreadable” lines?

Must the inducer *touch* the line whose color will spread?

What are the effects of changing the *relative orientations* of inducer and spreading lines?
**NEON AND TRANSPARENCY**

Many accounts of transparency follow in the tradition of Metelli’s analysis of algebraic relations among the luminances of four regions meeting at an X junction, of which the T junction of the previous page can be viewed as a degenerate example, with A = D.

**FAILURE OF CONTRAST**

(after DeValois and DeValois)

Food for thought: What about this pattern?

What is predicted ... from the standpoint of local contrast? ... from the standpoint of “cognitive expectations”?

**WHAT IS A LINE?**

Why have (fuzzy) perpendicular induction of BCS signals at line ends?

Consider the problem of localizing a line end. Positional uncertainty is worse in the direction of elongation -- relative to each receptive field scale.

A line is not a perceptual atom; rather it is a coherent statistical structure in a context.

(Think about perceptual changes when you approach a piece of yarn, a la Mandelbrot.)

**HOW THIN IS “THIN”?**

For a given receptive field size:

Inputs of two thicknesses:

For a thin line

no detector perpendicular to line end can respond “enough”

. . . based on bottom-up input alone.

End cut simulations of G & M 85a refer to such a situation.
Claim: Can't just go to smaller masks, because each scale must make an independent assay of boundaries. Why?

The claim that it's the "next" stage is highly suspect in a heterarchical feedback system. Cf. Gove, G & M, 1995.

IF NO END CUTS . . .

END CUTS

Visual system must synthesize a line end.

Claim: we cannot just use smaller filters. Why not?

NOTATIONS

\[ \text{[ ]}^+ \text{ denotes rectification ("half-wave")} \]

“complex cell”

“simple cells”
**END CUTS AGAIN**

Where does the synthesis of line end boundaries (*end cuts*) occur?

BCS model: First and Second Competitive Stages

Analog *in vivo*: “Hypercomplex” (i.e., *end-stopped complex*) cells of hypercolumns of V1 and/or V2.

Dotted box above symbolizes that all receptive fields overlap. (i.e., they have common centers.)

RFs have different orientations but same position; (a convenient fiction, but “nearly” true.)

**BCS: SHORT-RANGE COMPETITION**

*End cuts* (via 1985 mechanism)

Two stages of *short-range competition*

First:

- across locations
- same orientation

Second:

- same location
- across orientations*

* This nomenclature is from Starbucks, not from neurophysiology.

**ENDSTOPPED CELLS**

Complex and (even) “*simple*” cells may be *endstopped*.

How can you tell?

response:

- weak
- moderate
- strong
- zero**

* This nomenclature is from Starbucks, not from neurophysiology.

** Perhaps the response is only severely reduced from maximum.
**STATING THE OBVIOUS**

Newer diagram of *same* model equations ... to emphasize that first competitive stage generates *endstopping*.

Mechanism for generating end cuts:
- Two stages of short-range competition

**SECOND**

**FIRST**

**ENDSTOPPING!**

Moral: Take NOTHING for granted!

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**ORIENTED AND UNORIENTED**

*Should* the first competitive stage be *isotropic*?

as opposed to: or:

good for "thinning" contours enough for endstopping

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**ASIDE: BAD PLAY ON WORDS**

"Lateral inhibition" among neighboring cells with similarly oriented receptive fields can generate *endstopping*.

(Overlapping: ellipses are 10 times illustrated size.)

Note that this short-range competition among orientationally-sensitive cells occurs in all later versions of BCS/FCS, including the FACADE “successor” model, even though later publications rarely, if ever, show a diagram like that of the previous panel.
Summary to this point: Perpendicular induction of BCS signals occurs at line ends. Later, arguments will be advanced that the induction process is:

- positionally hyperacute, but orientationally fuzzy.

Claim: Induction exists because the visual system must compensate for inherent uncertainties of position and orientation in the information available to any single node, because of the finite size and elongation of simple cell filters (“masks.”)

So, within the processing scale for which a line is “thin,” information about the line’s termination cannot be adequately coded (where “adequately” means “strong enough boundary to prevent featural diffusion”) by local oriented contrast filters based on image data -- even if the line is “real” (in the sense of possessing unbroken luminance contrast) and noise-free. That is:

“All line ends are illusory.”

(Note: These mechanisms, first discovered by analysis of weird illusions, are critical for “normal” perception of everyday scenes.

(Yet another) Disclaimer

Note: Much of the material in the next several panels is of “historical interest” (at best!) In particular, details about the equations that follow for the First and Second Competitive stages of the BCS will not be “on the test.”

They are presented to help communicate the evolution of model mechanisms that is still ongoing. For example, the simulations of end cuts that follow, while illustrative of ideas that are still “operative,” employ mechanisms that have not proven robust for larger and more complex images. Pointers to some improved formulations appear in notes for Week 8.

In order to spot opportunities for improvements upon models, you need to develop the ability to “read between the lines” of the equations, so the following exercise may not be entirely futile!

First Competitive Stage

Shunting competition:

- within orientations, \( k \)
- across positions, \( pq \) to \( ij \)

For the excitatory term:

\[
\frac{d}{dt} w_{ij} = -w_{ij} + I + f(J_{ijk} - w_{ijk} \sum_{(p,q)} J_{pqk} A_{pqij})
\]

(Notation of Grossberg & Mingolla, 1985a)

Q1: Why no shunting in excitatory term?
Q2: Why the tonic input (always on, for all nodes)?

Second Competitive Stage

Begin with: push-pull opponent process

\[
x_{jk} = w_{ijk} - w_{ijk} \quad (A6)
\]

where orientation \( k \) is perpendicular to orientation \( K \)

followed by . . .
SECOND COMPETITIVE STAGE, CONTINUED

normalization across orientations*
at each position (dashed boxes)

\[ O_{ijk} = O(x_{ijk}) = C[w_{ijk} - w_{ij}]^+ \quad (A8) \]

\[ \frac{d}{dt} y_{ijk} = -D y_{ijk} + (E - y_{ijk}) O_{ijk} - y_{ijk} \sum_{m \neq k} O_{ijm} \quad (A9) \]

\[ y_{ijk} = \frac{EO_{ijk}}{D + O_{ij}} \quad (A10) \]

where \[ O_{ij} = \sum_{m} O_{ijm} \quad (A11) \]

* Cf. Grossberg, 1973 and “Heeger normalization model” (Heeger, 1993)

OLD AND IMPROVED

Alternate version of second competitive stage (from G & M, 1987):

\[ \frac{d}{dt} y_{ijk} = -Ay_{ijk} + (B - y_{ijk}) \sum_{m} w_{ijm} C_{mk} - (y_{ijk} + D) \sum_{m} w_{ijm} E_{mk} \]

A DOG/(A+SOG) equation for interactions among orientations:

accomplishes both “push-pull” competition at perpendiculars and normalization across orientations.

-- “smoother” across orientations than 1985 version
-- “milder” end cuts...

Gove, G & M (1995): The above is still not good enough!

COMPUTATIONAL THEORY OF TWO COMPETITIVE STAGES

Rationale: Equations A4 - A11, or their variants, should produce transformations such as the following:

Input to 1st comp (from masks):

Output of 2nd comp (to CC Loop):

\[ \text{normalization} \]

end cut

from nearby position:

from nearby position(s):

Total activity over ALL orientations at one position is roughly constant.

Annihilation by push-pull competition, “artifact cancelation”?

SPATIAL LOCALIZATION AND HYPERACUITY

Independent evidence for front end of BCS:

Badcock & Westheimer, (1985) Vision Research, -25-, 1259. found “. . . two separate underlying mechanisms, one concerned with the luminance distribution within a restricted region and the other reflecting interactions between features.”

flanking line

test line

Influence of a flanking line on perceived position of a test line.

Within the central zone:

like contrast flank attracts; opposite contrast flank repels.

(cf. contrast sensitivity of simple cells’ oriented receptive fields.)
MORE LOCALIZATION AND HYPERACUITY

Badcock & Westheimer, (1985)

"Outside this central zone repulsion effects are obtained independent of the contrast polarity of the flank . . ."

**Central zone:** elongated receptive field

**Outer zone:** isotropic (?) inhibition

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THERMOS QUESTION OF THE WEEK

Physiologist poking around V1 can be divided into two groups, who (act as if they) believe:

1. simple and complex cells really “like” thin lines and edges, or
2. the “right” way to study simple and complex cells is to use stimuli that are narrow-band in the spatial frequency domain.

A question that few if any physiologists seem to be asking is how do cells “know” how and when to **switch** from “edge detection” mode,

whereby a few cells respond strongly and suppress their neighbors with similar orientational tuning,

**to “smooth shading” or “shallow-gradient” mode,**

whereby many cells of similar orientational preference may respond over a wide region.

---

NOT YOUR FATHER’S EDGE DETECTOR

Is the BCS “just another edge detection algorithm”? It does begin with oriented contrast-sensitive filters as discussed.

But, its **rationale and behavior**

- with respect: FCS and filling-in;
- with respect: CC Loop for completion, grouping, and segmentation;
- with respect: treatment of textures as well as edges;
- with respect: smooth luminance gradients == “Boundary webs:” (to be discussed next week)

is more comprehensive than just “edge detection.”

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COOPERATIVE-COMPETITIVE NONLINEAR FEEDBACK

G & M, 1985: Use cooperative-competitive nonlinear feedback (CC Loop) to complete and sharpen boundaries.

Recall: **Perpendicular induction** at line ends:

Long-range cooperation wins over locally preferred orientations if the latter cannot support a coherent grouping.

(After Kennedy, 1979)
BOUNDARY GROUPING

Each line end induces a “fuzzy band” of “almost perpendicular” candidate directions for grouping:

(Q: Where is this fuzzy band in vivo?)

When such activations are aligned across perceptual space, cooperative completion of boundaries can occur.

FROM FUZZY TO SHARP

Why do we not always perceive multiple, or fuzzy, (illusory) contours?

Hierarchical resolution of uncertainty:
1) Need fuzziness to initiate grouping.
2) Risk loss of acuity.

CC LOOP is a decision process.

CHOOSE: The contextually best orientation
SUPPRESS: Other local orientations

VARIABLES AFFECTING CONTOUR COMPLETION

proximity \( r \) of center of “inducing unit” to center of “receiving unit”
alignment \( q \) angle formed by inducing unit’s center relative to preferred axis of receiving unit
orientation \( f \) difference in preferred orientation of inducing and receiving units

The biopole property

“Completable” perceptual gap can be bridged in one cycle -- no “iteration” is required to determine WHETHER to complete, (though there may be additional “shaping” of completed contours by a cascade or resonance that takes some time to establish.)

Completion via long-range cooperative units

fuzzy “AND” gate

**BIPOLES THROUGH THE AGES**

Grossberg & Mingolla, 1985  
Field, Hayes, & Hess, 1993  
Heitger & von der Heydt, 1993  
Williams and Jacobs, 1997

Cf. “relatability” -- geometric constraints on which contours get to group with which -- Kellman & Shipley, 1991  
Also, Ullman, Zucker, Mumford, Guy & Medione “tensor voting”

**WANTED: INTERPOLATION WITHOUT EXTRAPOLATION**

**DUALITY OF “DONOR” AND “RECIPIENT” UNITS**

Completion here?  
Possible completion sites

**DUALITY AGAIN**

Out field  
In field
IN AND OUT

Bipole “logic” is inward — Inputs needed at A and B to “activate” in the center.

Candidate cells (V1, V2) send signals outward via long-range, horizontal (axonal) connections.

Q: Is this business about outward propagation really a problem?

Williams: No, because “inward” and “outward” perspectives are equivalent geometrically (as noted in panels 9 and 10).

Mingolla: Yes, but nonlinearities of perceptual selection break the symmetry, so there is work to do . . .

REMINDER -- MODELERS AND PHYSIOLOGISTS:
“DIVIDED BY A COMMON LANGUAGE”

RECEPTIVE FIELD -- functional
Where on the retina will stimulation yield a response at this (cortical) cell?

KERNEL -- structural
Which network cells send inputs directly to this cell?

Kernels are trivial for a modeler to specify, but are generally not observable for a physiologist!
IMPLEMENTATION OF BIPOLE PROPERTY (1985*)

1) Compute separate sums, left and right

2) Separate saturation, left and right

3) Threshold the total of both sides above the saturation level for one side

RESULT: Completion occurs only when inputs come from both sides.

GOOD NEWS: Bipole functions as “statistical AND gate.”

* The idea was first published in 1985; the phrase “bipole property” in 1987.

BASIC BOUNDARY COMPLETION

In this simulation a single active node on each side of a bipole suffices to initiate feedback. Input nodes are at 15 and 25.

GOOD NEWS: Bipole functions as “statistical AND gate.”

Fig. 20 of G & M, 1985a. Note that caption refers to “filling-in,” -- a phrase now reserved for diffusion of featural activity in regions -- as opposed to boundary completion!

DYNAMICS OF BOUNDARY COMPLETION, 1985

Close inspection of this unpublished two-orientation simulation shows:

1) Bipoles complete mid-point of gap first (as opposed to growing a boundary out from regions of greatest support.)

2) Interior end cuts are first generated and then suppressed.

BAD NEWS: LOSS OF ANALOG SENSITIVITY

Likewise for other variables that affect perceptual completion strength, such as distance, alignment, etc.

Reason? -- FEEDBACK
“DIVIDED BY A COMMON LANGUAGE” REDUX

Any topological “closed loop” in network connectivity yields FEEDBACK. (modeler’s usage)

\[
\frac{d}{dt}(\text{blah}) = -yaddayadda + \text{somethingelse} \pm f(\text{blah})
\]

Flavors of cortical feedback:

1) horizontal connections within lamina (reciprocal)

2) closed local circuits, between laminae, within cortical area

3) “descending” connections between cortical areas (most common physiologist’s usage)

WHY FEEDBACK?

Possible computational benefits:

- Smoothing of curves
- Sharpening of completed contours
- Amplification of consistent information
- Synchronization
- Resolution of real/illusory conflicts

Data:

- *Visual persistence is longer for illusory contours than for real contours*  
  [Ming & Meyer, 1988]

- *Two masking regimes for illusory contours*  
  1st: at \( \approx 120 \) msec, 2nd: at “additional 140-200 msec”  
  [Ringach & Shapley 1996]

WHEN LESS IS MORE

More “real” contour . . . weaker illusory contour

after Kennedy, 1979

ILLUSORY CONTOUR STRENGTH

Lesher & M, 1993
GREG LESHER, CNS ‘93

Known aliases:
- Fingers
- The Immortal

First CNS student to contribute to the empirical base of human knowledge via psychophysics

Quotation: “Pop tarts! YESSSS!!”

Cofounder: Enkidu Research

ANALOG-SENSITIVE COMPLETION

proportional to “support ratio” vs. inverted-U

Shipley & Kellman, 1992
Lesher & Mingolla, 1993

cf. Soriano, Spillmann, & Bach, 1994 (shifted gratings)

BCS: COOPERATION AND COMPETITION

few lines, wide spacing
more lines overcome slight inhibition from neighbors

 crowding lowers overall effective input to cooperation

cf. hyperacuity

COMPLETION BY LONG-RANGE HORIZONTAL CONNECTIONS

layers 2/3, V1 and V2

Excitation: monosynaptic
Inhibition: disynaptic, via interneuron

RESULT: “Bipole property”
a single input on one side of a cell does not activate it, but two inputs do (one on each side).

WHY? Inhibitory interneuron saturates before cell that receives excitation along apical dendrite.

G, M & Ross, 1997
If the claim on the previous slide seems a little “fishy” to you, congratulations on your intuition.

Please check the “fine print” of the next panel, which describes an additional condition that needs to be satisfied to get this scheme to work.

Note also that Grossberg and Raizada’s method of implementing the bipole property -- mentioned but not described in detail in following panels -- is somewhat different still. For that one, you simply have to read the papers.

DYNAMICS OF COMPLETION, 1997

Initial “outward” activation subsides.

- - - - - - - - - - - - - - - time 4
- - - - - - - - - - - - - - - time 3
- - - - - - - - - - - - - - - time 2
- - - - - - - - - - - - - - - time 1

NOTE: Local connectivity ALSO needed in 1997 version: Bipole cells need input from both nearest neighbors OR direct bottom-up input to remain active.

CONTEXTUAL PROCESSING

GROUPING CIRCUITS OF LGN, V1 & V2

Model V2 circuits: similar to V1, but with larger receptive fields

Bipole cells of layers 2/3 send feedback via layer 6 cells...

to the same “center-surround” circuit of layer 4 that receives inputs from “earlier” brain areas.

Results:

Analog-sensitive completion

Context-sensitive criteria for grouping “scaled against” bottom-up inputs

figure courtesy of Raj
Raizada’s Results

Steve Grossberg and recent CNS graduate Rajeev Raizada extended the bipole circuit idea in the development of the “LAMINART” model depiction shown in the previous panel.

“FOLDED FEEDBACK”:
LAMINART gives an account of how perceptual grouping and attentional mechanisms can share common circuits despite having different computational constraints.

Details (including paper downloads) are available at: http://www.cns.bu.edu/~rajeev

AND NOW FOR THE BAD NEWS

The “new” bipole circuit has several variants; most are still “finicky” w/r/t parameters, input sizes, dynamic range, etc.

Note in particular how inhibitory interneurons are handled.

Nonetheless, present research is accelerating the “convergence” of certain results of adaptive resonance theory (ART) and those of specialized models of vision circuits . . .

GESTALT GROUPING SIMULATIONS

Proximity:
strengthens horizontal grouping breaks vertical grouping

Fig 6, G, M & Ross, 1997
**CONTEXT-SENSITIVE GROUPING, 1985**

G & M, 1985b, Figs 23, 24

**ENHANCEMENT OF COHERENT INPUTS**

Ross, G & M, 2000

**APPLICATION: IMAGE ENHANCEMENT**

input

boundary

feature

filling-in

M, Ross, & G, 1999

Solid horizontal bars break vertical groupings

Ross, G & M, 2000
Evidence for bipole connectivity in cortex continues to accumulate.

It would be hard to “fake” anatomical data more supportive of the bipole geometry proposed in 1985 (panel 10 of these notes) than what is shown on the next panel.

Also, the physiology described in the subsequent panels has been developed further than we can cover adequately in this class.

von der Heydt, Peterhans, & Baumgartner, 1984

<table>
<thead>
<tr>
<th>Stimulus</th>
<th>Probe location</th>
<th>Cells in V2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Response?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>YES</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NO</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NO</td>
</tr>
<tr>
<td></td>
<td></td>
<td>YES</td>
</tr>
<tr>
<td>(more contrast)</td>
<td></td>
<td>NO</td>
</tr>
<tr>
<td></td>
<td></td>
<td>YES</td>
</tr>
</tbody>
</table>

Evidence for receptive field:

Also Peterhans & von der Heydt (1988).

MORE ON vdH, P, & B

Horizontally tuned cells:

Probe location:

<table>
<thead>
<tr>
<th>Stimulus</th>
<th>V1 response</th>
<th>V2 response</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Strong</td>
<td>Strong</td>
</tr>
<tr>
<td></td>
<td>Weak, with orientationally FUZZY receptive field</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>Stronger, with orientationally SHARPER receptive field (same cell as above)</td>
<td>None</td>
</tr>
</tbody>
</table>

Evidence for:
1) orientationally fuzzy end cuts
2) oriented, long-range cooperation.

NOTE: There has been much controversy re: completion in V1 and whether shifted grating contours are “illusory.”


CONTRAST-SENSITIVE GROUPING

Collinear flankers

enhance response to near-threshold target

suppress response to high contrast target

Polar et al. 1998
Cat Area 17 (V1)

STILL MORE

SIMULATION OF POLAT et al. DATA

Details: Rajeev Raizada: http://www.nmr.mgh.harvard.edu/~raj/
Figure on previous panel: Left side -- This plot summarizes psychophysical data from trials of one observer in a tilt illusion experiment. The observer controlled the orientation of a central line segment displayed in juxtaposition with two symmetrically flanking lines whose actual orientation was 5 degrees from the vertical. The observer's task was to make the central line appear vertical. The data show regions for which attractive (blue) and repulsive (red) tilt illusions were obtained. Right side -- Summary of excitatory and inhibitory zones of influence for flanking stimuli on single cells of vertical orientational preference whose receptive fields are centered in the diagram.

Geisler, Perry, Super, and Gallogly 2001
I'd like to thank the guy who wrote the song
That made my baby fall in love with me

Who put the bomp In the bomp bah bomp bah bomp
Who put the ram In the rama lama ding dong
Who put the bop In the bop shoo bop shoo bop
Who put the dip In the dip da dip da dip
Who was that man, I'd like to shake his hand
He made my baby fall in love with me [Yeah]

... ... ...

Darling, bomp bah bah bomp, bah bomp bah bomp bomp
And my honey, rama lama ding dong forever
And when I say, dip da dip da dip da dip
You know I mean it from the bottom of my boogity boogity boogity shoo

Song: **Who Put The Bomp** (In The Bomp Bah Bomp Bah Bomp?) — 1961 — 2:43 Artist: Barry Mann
LP/CD: Not available — ABC
Writers: Barry Mann ~ Gerry Goffin
Transcribed by: Char Star
AS SUGGESTED BY . . .

Murphy & Sillito, 1987

Some cells of LGN exhibit something that looks pretty darned like endstopping -- firing only if a line ends in a receptive field’s excitatory center.

The “experimental side” below refers to a cell whose length tuning looked as above before its corresponding V1 hemisphere was aspirated.

SIMULATION

input          feature
(buttons!)

boundary       filling-in

SWITCHING OFF COMPLETION

Small obstructions can “break” illusory contours that would otherwise form.

SPATIAL IMPENETRABILITY

Why do not all collinear contour fragments complete across intervening contours?

Mechanism for “spatial impenetrability:”

*Yes, dipoles AND bipoles
You say “TO - MAY - TO,” I say “TO - MAH - TO,”
you say “DI - POLE,” I say “BI-POLE.”
Let’s call the whole thing off!

Horizontal signals are everywhere, but form a majority only at line ends.

Note: spatial impenetrability includes options on: “occlusion,” “transparency,” “figure-ground,”
“border ownership,” “T-junctions,” “amodal completion,”
extrinsic and intrinsic line ends ...
See section 13 of G & M, 1985b (*Perception & Psychophysics*)

for a discussion of the how the potential boundary groupings compete and interfere with one another.

Perceptual grouping is an autonomous (i.e., “protected” from top-down interference from learned expectations) real-time statistical decision-making process.