

WEEK 4: CONTRAST SENSITIVITY AND SPATIAL SCALES . . . AND BRIGHTNESS

- 1) Structural scales: functional scales :: kernels: receptive fields
- 2) Detectors and filters -- linear systems approach to vision
- 3) Contrast sensitivity and spatial scales
- 4) Peak shifts and lateral inhibition*
- 5) Brightness perception: Quantifying percepts
- 6) Isomorphistic and nonisomorphistic theories
- 7) Craik-O'Brien-Cornsweet (COCE) effect

MODEL COMPARISONS

To put recent developments in a historical perspective, we have contrasted

Grossberg's shunting network approach
including feedback and resonance

with

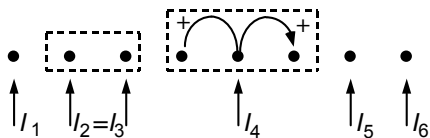
Marr's computational approach

Next, we will contrast Grossberg et al.'s work with models based on linear systems theory

GROSSBERG, 1973 FAQ 1

Q: What's the deal with "cell or population"?

A: Assume connections in a network can create "pools" (or "blocks") of nodes responding identically to the same input. It may be mathematically convenient to treat these pools as single entities.



Possible mechanism for getting around single node saturation limit (upper bound), as in:

$(B-x_i)$ (excitatory terms).

GROSSBERG, 1973 FAQ 2

Q: When can you solve directly for the equilibrium state of a differential equation by setting derivative to zero and solving resulting algebraic equation?

$$\frac{d(\text{blah})}{dt} = 0$$

A: First ask: Am I sure that *any* equilibrium exists? If so, is there only one? Moreover, is the system governed by the equation *uniformly asymptotically stable*, with a single attractor?

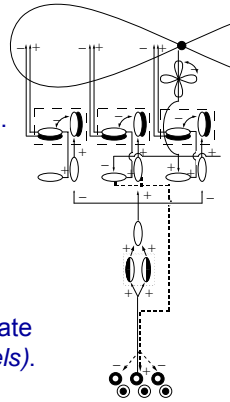
This is unlikely, to say the least, for large, nonlinear, *recurrent* networks.

ROOTS

Many of the developments of the vision theory developed by Grossberg and colleagues from the 1980's through the present were foreshadowed in Grossberg, 1983.

They can be viewed as harnessing the intuitions of theorems on recurrent (feedback) networks first explored in Grossberg, 1973, but in networks with increasingly elaborate *distance-dependent interactions (kernels)*.

Note: the theorems will no longer hold, but system behavior may approximate what the theorems suggest.



FEATURE DETECTION

Common theme:

Scenic input is *too* rich in (bits of) information; the visual system has no choice but to perform some kind of *image decomposition*, to “extract” important information.

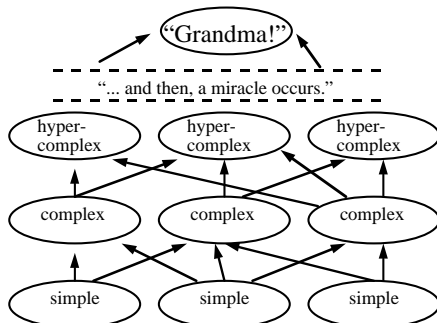
Barlow, 1953 introduced the idea of “*trigger features*” for cell responses.

Hubel & Wiesel, 1959, etc. extended the range of *feature detector* theories of visual processing.

Observation: Certain cortical cells appear to respond best (in some cases almost exclusively) to simple but specific image features (e.g. edges, line ends, corners).

THE “GRANDMOTHER CELL” MODEL

Hubel and Wiesel developed a *hierarchical* model of organization of visual cortex -- still an influential view -- in which successive layers of cells respond to specific *combinations* of features coded by a previous layer.



MODELING AS POETRY

Is the idea of visual cortical cells as *feature detectors** the right metaphor. (Yes, I said metaphor.)

What else could they be?

*The word “feature” is used in many, and contradictory ways in the field of vision.

DETECTORS VS. FILTERS

A **detector** (“active”) responds only to the presence of “specific tokens” or “signature patterns” in an image.

A **filter** (“passive”) responds to any input token -- up to the limits of the filter’s resolution or range -- but gives strongest responses to a small (?) range of token values.

Consider: You would want an “*unbroken* line **detector**” to respond to this, but not to this.



This result is hard to achieve (over variations in contrast, etc.) with a conventional (“convolution”) filter.



Is this just a question of semantics?

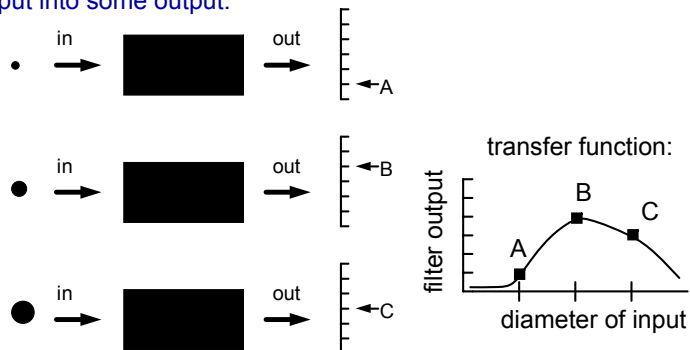
I.e., is the distinction a matter of definition of “specific tokens” vs. “small range of token values.”

Is a **detector** just a “**filter** with a threshold”?

Sociology of science: Whether one speaks of visual cortical cells as detectors or as filters is correlated with the field of study in which a researcher earns academic degrees!

FILTERS AND TRANSFER FUNCTIONS

Consider a filter as a “black box” that transforms each input into some output:

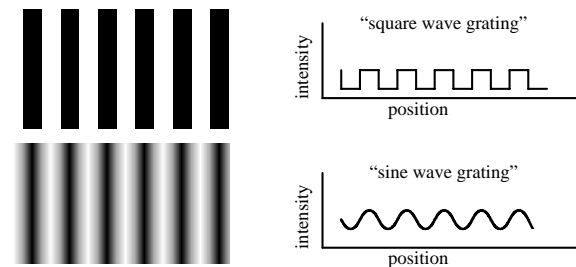


If the value of the output exhibits some systematic relationship with some measurable aspect of the input, we can speak of the **transfer function** of the filter.

CONTRAST DETECTION AND SPATIAL FREQUENCY

Cornsweet 1970 describes the visual system as consisting of a single “channel” -- which acts as a filter whose response depends (in part) on the *spatial frequency content* of the image.

Cornsweet writes of a **modulation transfer function (MTF)** because the measure of the input that is plotted against output is the *modulation* of the *luminance* of the image (“intensity”).



SPATIAL FREQUENCY

Periodic stimuli can be classified by the **spatial frequency** of the modulation of their luminance.

Spatial frequency: the number of times -- **cycles** -- that **luminance** changes from some *minimum* to some *maximum* value over a fixed distance, given in *degrees* of visual angle.

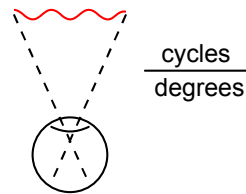


Image regions containing only *low spatial frequencies* generally look relatively *homogeneous*; those containing only *high spatial frequencies* generally appear to have a lot of “detail” or “texture.”

Q. What is the relationship of spatial frequency to Grossberg's usage of the word “scale”?

HUMAN POINT SPREAD FUNCTION

Assume that the eye is a perfect lens, ignoring: spherical aberration, chromatic aberration, diffraction, scatter, . . .

The imperfections can be usefully “accounted for,” paving the road for *spatial frequency methods*, and attendant formalisms, e.g. linear systems theory; Fourier analysis and synthesis, wavelets, etc.

POINT SPREAD FUNCTION AGAIN

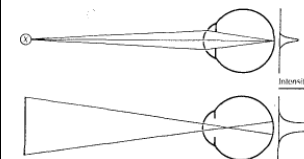


Fig. 3.21 Diffraction of light by the pupil of the eye. The width of the retinal light distribution is exaggerated. (From Cornsweet, 1970.)

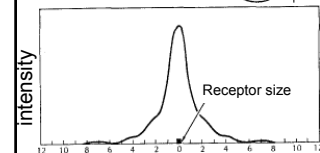


Fig. 3.27 Light distribution on the retina for a fine bright line object, calculated from the curve in Figure 3.26. The black rectangle represents the diameter of a retinal receptor in the central fovea. [After Westheimer and Campbell (1962), subject J. K. 3 mm pupil.] (From Cornsweet, 1970.)

Distance from center of geometrical image (minutes of arc)

NOTE: We can perceptually “resolve” displacements of thin lines at distances *smaller than the diameter of a single photoreceptor!*

SINUSOIDAL GRATINGS

The visual system can be *probed* by measuring its response to stimuli that contain only *one* spatial frequency, or a carefully controlled combination of stimuli at specific spatial frequencies.

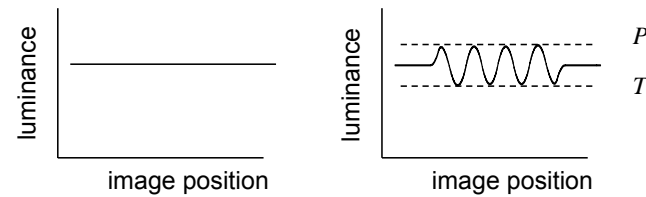
Strategy: For measuring an unknown system, make your *probe* as simple as possible, and know all of the probe's characteristics with respect to dimensions of measurement.

Tradeoff: "*Ecological validity*" -- where did you last see (only) stripes with sinusoidal luminance modulation?

HUMAN MODULATION TRANSFER FUNCTION (MTF)

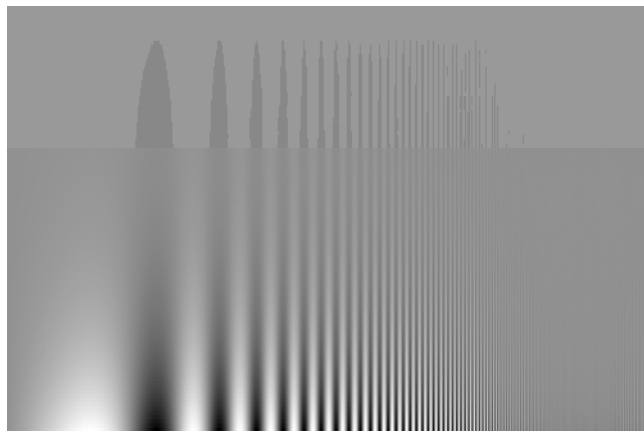
Sinusoidal stimuli are used to measure the **threshold response** of the human visual system *as a function of spatial frequency*.

To be found: **minimum contrast** necessary to *detect* the presence of a sinusoidal modulation of luminance of a certain spatial frequency

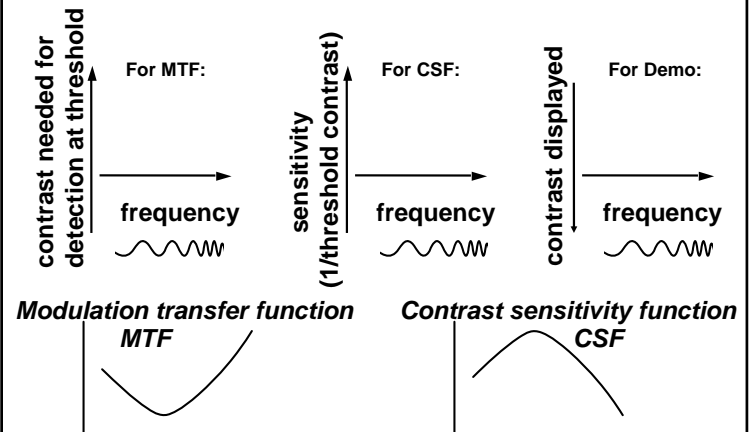


CAMPBELL-ROBSON CONTRAST- SENSITIVITY DEMO AT

http://ohzawa-lab.bpe.es.osaka-u.ac.jp/ohzawa-lab/izumi/CSF/A_What_is_CSF.html



MTF & CSF



The **more modulation** you need to detect a grating at a given frequency, | the **less sensitive** you are to contrast at that frequency.

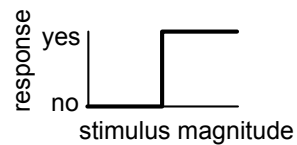
THRESHOLD CONTRAST FOR DETECTION

Gabori Attack!!

Download Gabori Attack (Mac/Windows)

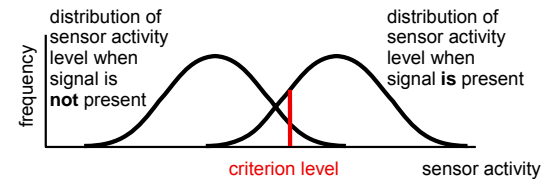
Do you or do you not see *anything* on this trial?

The question appears binary, but do the processes involved in exceeding a sensory threshold behave like step functions?



SIGNAL DETECTION THEORY

Instead: Consider threshold sensitivity as a stochastic process, and use concepts from **signal detection theory**.



The placement of the criterion level for output of positive response depends on “payoffs” for *false positives* vs. *misses* in signal-present cases.

For more, see Chapter 2 of **Yantis**.

SIGNAL DETECTION METHODS

Common assumptions:

- 1) **Normal distribution** of sensor activity
- 2) **Same variance** of sensor activity **with or without** signal present
- 3) **known receiver characteristics** (e.g., transfer function)

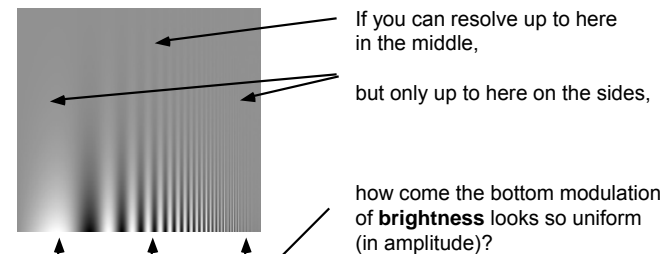
For multi-channel detectors, add:

- 4) assumptions about **superposition or probability summation** for responses of separate channels into a single “yes or no” output (See –Borg-Graham, supplementary, Week 2)

Just as with kernels and receptive fields, **“thresholds”** are trivial to **set** in a network simulation, and difficult to **measure** in real life.

SUPRATHRESHOLD PERFORMANCE

Query: If the visual system is so much more sensitive in the middle spatial frequencies than at the extremes, why is it that, along the bottom of the figure, where you can notice the contrast modulation across virtually the entire frequency range, the resulting modulation of **brightness** is essentially **homogeneous** throughout that frequency range?!



In other words: **What are the units of brightness perception?**

A point to ponder:

Some students in previous editions of CN530 have asked about the utility or the “place” of the material in the immediately preceding section in the course, as we will not subsequently make “direct” use of it. We cover it for several reasons, including a historical survey of methods that have been used to understand vision, and because the data of contrast sensitivity are still important “anchors” that a complete theory of vision has to address, even though it has proven difficult to “build up” a rich theory of vision from simple model elements like Fourier primitives that are so often used as tools of stimulus construction in contrast sensitivity research.

Note also that even a highly nonlinear system may appear to behave linearly within certain narrow operating ranges, such as are explored by many threshold detection tasks.

STRUCTURAL AND FUNCTIONAL SCALES

The measured magnitudes of perceptual phenomena (e.g. the strength of the *café wall illusion*) may not be as directly “readable” from the sizes of anatomical structures, . . .

as would be the case if the visual system were more “linear.”

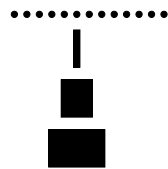
anatomy	physiology
geometry	dynamics
structural scales	functional scales

STRUCTURAL AND FUNCTIONAL SCALES AGAIN

In a network model, a *kernel defines a structural scale*:
e.g., a Gaussian of unit weight, $\sigma = 2$, truncated at 5 nodes from center.

The *functional scale* of this network’s response to inputs of varying sizes might need to be determined by simulation, if the network involves nonlinear feedback (no analytic solution.)

I.e., how many nodes have their activity affected (either excitation or inhibition) as a function of bar thickness?



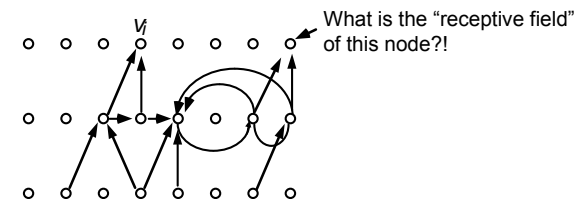
CONTEXT DEPENDENCE

The measured size of many cells’ receptive fields depend on the nature of (current and prior) stimulation.

For *feedforward* anatomies, **structural** and **functional scales** may be (more or less!) directly related.

Once *feedback* (*recurrent connections*) exists -- whether the feedback is between layers or *lateral* within a layer--

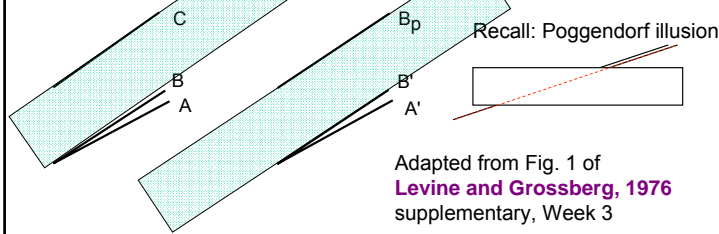
functional scales become much more “interesting.”



FUNCTIONAL SCALES AND PEAK SHIFT

Consider Blakemore *et al.*'s, 1970, **angle expansion illusion**, as described by Levine and Grossberg, 1976:

"If two lines forming an acute angle are presented to a subject and he is asked to place a third line parallel to the other two, he will err in the direction of perceiving the angle as larger than it really is."



Translation of above quote:

Line Bp is (really) parallel to line B'; line C is not parallel to line B. Nonetheless, Line Bp is not perceived as parallel to line B', but Line C IS perceived as parallel to line B.

Peak Shift

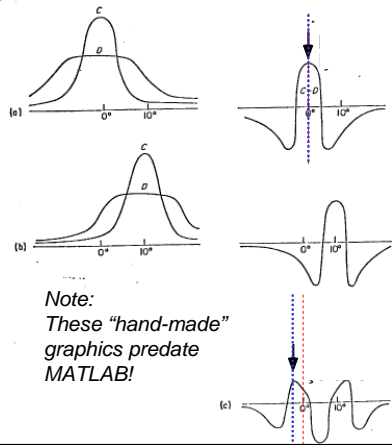
Blakemore *et al.*'s hypothesis:

Shift in perceived angle is due to **lateral inhibition** among cortical neurons that are tuned to different **orientations** of contrast. -- Cf. "**phase shift.**"

The idea of a peak in activity in response to an input being shifted from where it might otherwise occur because of some contextual change in circumstances -- e.g., "extra" inhibition from a second input OR "extra" excitation from a second input -- is so generic that it would be difficult to overstate the importance of learning a bit about how peak shifts "work" in network models.

LATERAL INHIBITION AND PEAK SHIFTS

Levine & Grossberg, 1976: a node's preferred angle-of-contrast is coded by its **position** within a network -- "**on-center, off-surround**" **in orientation space.**



Response of network to single input at 0°.

Response of network to single input at 10°.

Note: These "hand-made" graphics predate MATLAB!

The peak responses shift "outward" from corresponding single-input locations when 0° and 10° inputs occur simultaneously.

VARIETIES OF LATERAL INHIBITION

Levine and Grossberg, 1976 goals:

Classify outcomes of **different kinds of "lateral inhibition:"**

additive
$$\frac{dx_i}{dt} = -Ax_i + \sum_{m=1}^n K_m C_{mi} - \sum_{m=1}^n K_m D_{mi}$$
 Eq. (10), p. 486

shunting, feedforward, **no** hyperpolarization

shunting, feedforward, **with** hyperpolarization

shunting, feedback

Notational remark: In L & G, 1976, p. 487

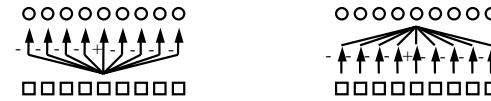
$$I_i = K_m C_{mi}$$

implies that a Gaussian weighting of *inputs*, (as well as of feedback signals) exists.

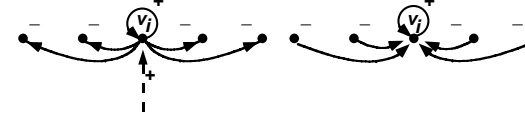
Also, PUN ALERT: “net inhibition”

ANATOMIES OF COMPETITIVE NETWORKS

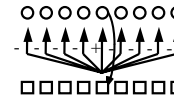
Feedforward:



Within-layer (a.k.a. “horizontal” or “lateral”) feedback (recurrent)

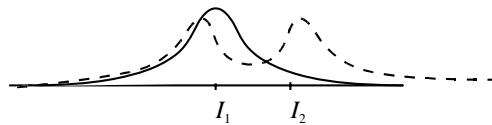


Between-layer feedback (recurrent)



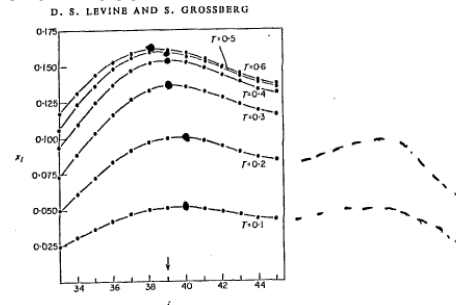
INFERENCES CONTINUED

L & G claim: Peak shift can occur in different arrangements of subtractive and shunting inhibitions. The inhibition is provided by the distant dependent negative weighting.



FEEDBACK AND TIME

In a simulation of a recurrent network, *G & L* demonstrate the importance of **temporal factors** in the “balance” of excitation and inhibition.



“Fig 10 *Inward* peak shift, indicated by heavy dots in figure, becomes *outward* as recurrent inhibition “builds up” over time!”
Think about “*structural vs. functional scales.*”

ON THE ROAD

BAD NEWS: We're lost!
GOOD NEWS: We're progressing swiftly!

- Week 1: Overture
- Week 2: Simple shunting networks
Grossberg/Marr debate
- Week 3: Basic physiology
- Week 4: Structural and functional scales
More shunting network background
Linear systems in vision
Filters and detectors
X You are here.
Brightness perception

When do we find out what the *units of vision* are?

LEARN THIS TERMINOLOGY*!!!

Photometric measures of light intensity reaching some point (employed in neurophysiology and psychophysics) are weighted by human sensitivities (optics of cornea, lens, pigment absorption spectra, etc.) while **radiometric** measures (physics) do not. (Energy that does not stimulate human photoreceptors *does not count* for photometric measures.)

Illuminance is the amount of visually effective light falling on a surface. (That light may or may not ever reach a photoreceptor!)

Luminance is the amount of visually effective (photometric) light emitted by some source (or, in practice, reflected off some surface).

Brightness is (used by many to mean) a subjective measure of sensation associated with the magnitude of luminance of a stimulus patch viewed in isolation on a surround of zero luminance. (DIM to BRIGHT.)
 Related (??) usage: "Subjective estimate" of *luminance* (!) of an area of a scene.

Lightness is (used by many to mean) a subjective measure of the relative "gray value" of a luminance patch, viewed on a surround of nonzero luminance. (DARK to LIGHT, or BLACK to GRAY to WHITE). Related (??) usage: "Subjective estimate" of reflectance of a surface area. (Adapted from Uttal, 1976)

BRIGHTNESS* PERCEPTION

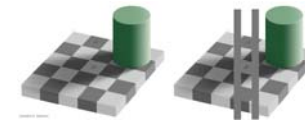
- 1) Brightness perception: Quantifying percepts
- 2) Isomorphistic and nonisomorphistic theories
- 3) Craik-O'Brien-Cornsweet (COCE) effect

Next week:

- 5) Brightness assimilation
- 6) Grossberg and Todorović (**T**) implementation of BCS/FCS

*We will also be talking about LIGHTNESS PERCEPTION.

Even a few moments at Ted Adelson's demo page



should convince you that there is a tremendous amount of complexity in the domain of brightness and lightness perception.

To date, no model has given a comprehensive account of all known perceptual effects.

We will focus initially on models that do a reasonable job on a subset of known effects, conceding limits on scope from the outset.

Later, we will briefly describe some promising paths for extension of models.

THE PLAN

- 1) **T** (1987) relates to the models of brightness perception, especially with regard to *motivation* for “**filling-in**”
- 2) Cornsweet’s analysis of the Craik-O’Brien-Cornsweet Effect
- 3) Background for **G & T** (1988) simulations

MODELS OF BRIGHTNESS PERCEPTION

(After **T**, 1987)

Styles of theories:

- Nonisomorphistic
- Cognitive
- Mechanistic (**Filling-in** and “**Integration**” theories)

Goal: To describe *magnitude*, M , of brightness sensation as a function of *luminance*, L : $M = f(L)$

What about $f(\)$? Is it . . . *linear*, . . . *a power function*,
. . . *logarithmic*? . . . (at least!) *monotone*?

The previous panel sidesteps a major issue:

What is the **spatial layout** of the region whose brightness magnitude we are to judge with respect to its surrounding regions?

As we will later see, *everything* affects this judgment:

Whether there is one surrounding region or many . . .

Whether the region to be judged has the highest or lowest luminance, or some intermediate luminance . . .

The “figure-ground” relationships in the scene . . .

Slant in depth, corners in depth, curvature in depth . . .

For now, we will consider only the simplest spatial arrangements.

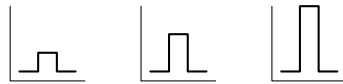
Note: There is much confusion about the nature and even the number of dimensions of achromatic color experience:
Brightness -- dim to bright vs.. **Lightness** -- black to white

Can one have a “dim” white? . . . a “bright” black?

Katz, 1935 also includes “pronouncedness” and “insistence” as dimensions of achromatic color, specifically to get at distinctions such as “white surface in bright light” vs. “white surface in dim light.”

Note also that **Tony “The Vlad” Vladusich** has many and interesting things to say re: brightness and lightness.

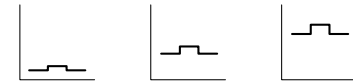
WOULDN'T IT BE NICE?



Desired simplicity:
Perceived magnitude is always some function of luminance.

E.g. **power law**: $M = kL^n$ is often found when an observer is asked to report the **subjective magnitude** (e.g. brightness) associated with a test region, relative to some *constant background* (“*magnitude estimation*”).

BUT, HANG ON ...

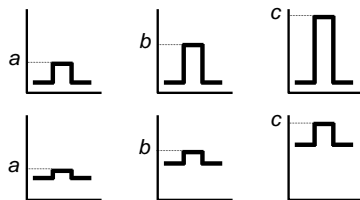


Compare last panel to Weber/Fechner paradigm for **just noticeable differences -- JNDs** where *luminance* of a “*target region*” and the *background covary*, yielding a **logarithmic law**, e.g. $M = k \log(L)$.

$$\frac{\Delta I}{I} = C$$

In any case, we still desire, for some f , $M = f(L)$.
 Is inverse of f well-defined? For that matter, is f well-defined?

UNFULFILLED DESIRE: BACKGROUND EFFECTS

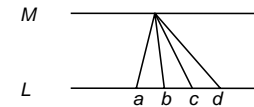


In other words,
 (1) you are trying to find a function that relates the **magnitude of a visual stimulus** in some region (luminance, given by the *height of the six central plateaus in the above plots*) to the **magnitude of some internal sensation**.

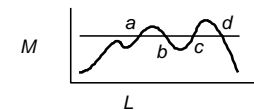
(2) The answer you get **depends on the way you set up the backgrounds**, as well as on the magnitude of the “stimulus,” in the sense that the *shape* of the resulting response function differs.

TROUBLE AHEAD, TROUBLE BEHIND

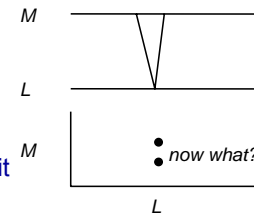
1) *Many* values of L can map to *one* value of M .
 e.g., “*brightness constancy!*”



2) *One* value of L can map to *many* values of M , as in Craik--O'Brien--Cornsweet Effect.



Bottom line: Power and log laws only work for (simple situations, such as s) *target on a homogeneous background*; to explain more requires *tasting the fruit of the tree of knowledge*.



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SAME L, DIFFERENT M

All the diamonds in the same row as the one marked "1" → have the same luminance as all the ones in the row marked "2". (!) →

Figure source:
Logvinenko A D, 1999 "Lightness induction revisited"
Perception 28 803--816

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CRAIK-O'BRIEN-CORNSWEET EFFECT

long-range interactions in what we **see** in a *region*.

After Todorović, 1987

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BRIGHTNESS AND SPATIAL FREQUENCY

Consider COCE:

Nonisomorphic account (e.g. Cornsweet): Illusion is based on *attenuation of low spatial frequency information* -- cf. **MTF**.

Square wave is "composed" of sine waves at many spatial frequencies, and *we are not very sensitive to the low spatial frequency components*.

So: a luminance *step* and a luminance *cusps* are (nearly) functionally equivalent. (Cf. Cornsweet, p 346, Arend & Goldstein, p 67.)

Bonus question: What would be a good direct test of this idea?

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NONISOMORPHISTIC ACCOUNT OF COCE

Luminance:

Input amplitude X spatial frequency:

CSF "weighting"

Weighted input X spatial frequency

Reconstructed profile
C calls this "brightness"!

CRITIQUE OF NONISOMORPHISTIC ACCOUNT OF COCE

Nonisomorphistic account:

Through early visual processing:

square wave: luminance *step* goes to neural *cusps*

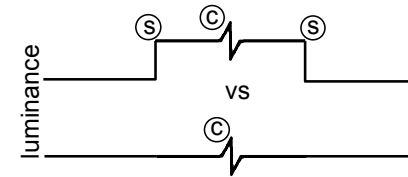
COCE: luminance *cusps* also goes to neural *cusps*. **Q.E.D.**

Note: The transformation of C's account on the previous panel -- attenuation of low spatial frequencies -- can also be phrased in terms of the "natural" result of *center-surround processing*.

Proponents of isomorphistic account argue that we also need an explanation for why *any* neural *cusps* looks like a brightness step.

GREAT MINDS THINK ALIKE

T (1987) shows that the *configuration of luminance discontinuities* ("edges") can have profound effects on brightness, **even in places distant from the cusp.**

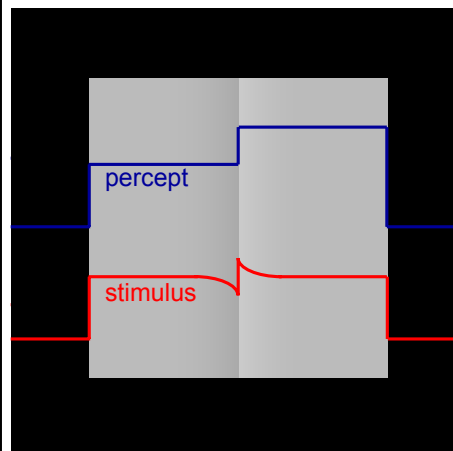


CLAIM: **Both** the *step edges* ("s") and the *cusp* ("c") are implicated in experiencing the COCE in the above configuration. NOTE: Cornsweet's account *only* deals with the cusp.

Resulting conclusions:

- 1) A **filling-in** process is needed (to turn cusp into a step.)
- 2) **Boundaries** are needed to contain filling-in. (Sound familiar?)

CRAIK-O'BRIEN-CORNSWEET EFFECT



long-range interactions in what we **see** in a *region*.

After Todorović, 1987

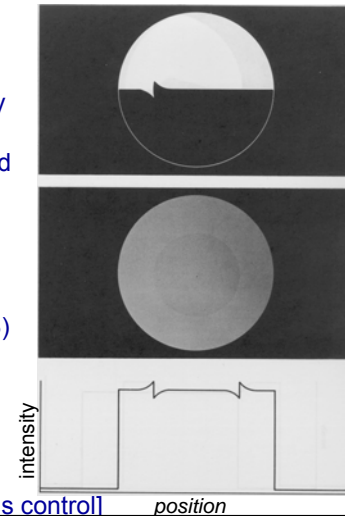
PSYCHOPHYSICS IN THE FIRST CENTURY B.C.*

Note that the spinning disk apparatus -- the standard means of generating smoothly varying luminance profiles before the computer-controlled CRT -- guarantees that a *closed region bounded entirely by a luminance cusp* is generated!

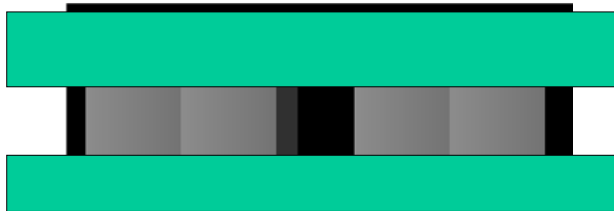
(from Cornsweet, 1970, p 273)

Compare to the T (1987) configuration of COCE.

*Before Computers
[in widespread use for stimulus control]



THE THIRD DIMENSION



same luminance profile in horizontal cross-section of the two figures

See [Dan Kersten's web demos](#)

Knill, D. C., & Kersten, D. (1991). Apparent surface curvature affects lightness perception. *Nature*, 351, 228-230.

LAMINAR CORTICAL DYNAMICS OF 3-D SURFACE STRATIFICATION, TRANSPARENCY, AND NEON COLOR SPREADING

Vision Research, 45 (2005) 1725-1743

With Stephen Grossberg

3D parsing of partially occluded surfaces

How does the laminar circuitry in areas V1 and V2 generate 3D percepts in response to 2D pictures and 3D scenes?

CONTRAST RELATIONSHIP IN TRANSPARENCY



Unique transparency



Bistable transparency



No transparency



The same geometry

CONTRAST RELATION IN TRANSPARENCY

Single polarity reversal
 Unique transparency

No polarity reversal
 Bistable transparency

Double polarity reversal
 No transparency

How does polarity alignment influence transparency

Adelson, 2000; Anderson, 1997; Beck, 1984;
 Metelli 1974; Watanabe and Svanag, 1992, 1993

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CONTRAST RELATIONS CAN INDUCE NEON SPREADING

This contrast relation supports neon spreading

Percept

Over

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CONTRAST RELATIONS CAN BLOCK NEON SPREADING

No neon spreading

Geometry is the same as the neon case

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LOCAL CUES

Polarity reversing T-junction
 Non-Neon

Polarity preserving T-junction
 Neon

The laminar architecture should treat contrast relations in a way to let it overcome the absolute values of contrast

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**POLARITY ALIGNMENT INFLUENCES
TRANSPARENCY
AND NEON SPREADING**

How early does this polarity sensitivity occur?

Claim: It occurs at layer 4 in V1

Why?

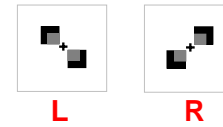
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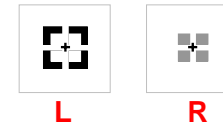
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SAME OCULARITY OF CONTRAST

Same ocularity of contrast can induce neon



Different ocularity of contrast can block neon



Takeichi, Shimojo and Watanabe, 1992

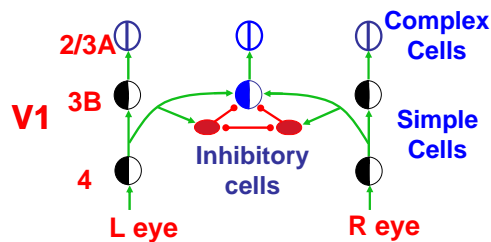
The contrast polarity constraint is MONOCULAR

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LAMINART CIRCUIT



Grossberg and Howe (2003)

Binocular fusion occurs in layer 3B of V1

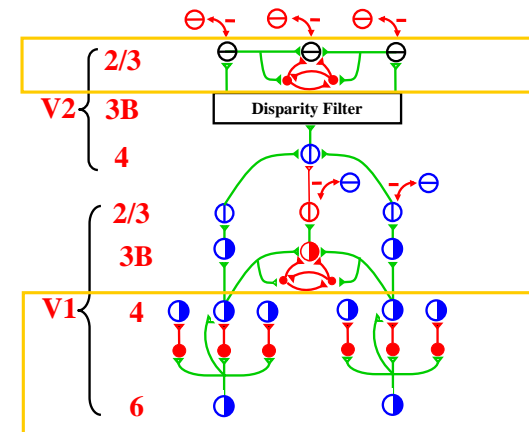
Hypothesis: The polarity-specific monocular process is in layer 4

Claim: This process is monocular polarity-specific competition

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3-D LAMINART CIRCUIT



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V2 Grouping pools opposite polarities

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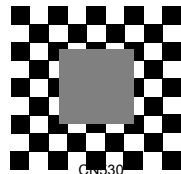
SUGGESTS NEW EXPERIMENTS

Preference for **like-polarity inhibition** in layer 4 of V1 is proposed to develop from normal visual statistics

Grossberg and Williamson (2001)

What happens to this preference when animals are raised in abnormal visual environments?

e.g., **opposite polarity textures?**



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SELF-NORMALIZING INHIBITION FROM V1 6-TO-4

Multiple predicted roles:

Contrast gain control of BU inputs from LGN

Selection and analog coherence of groupings

Target of top-down attention

Influences transparency percepts

Suggests totally new kinds of experiments

Who will run with this opportunity?!

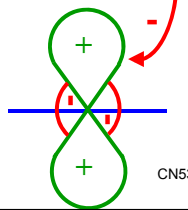
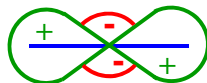
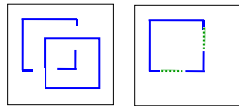
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HOW ARE BOUNDARY GAPS CREATED AND COMPLETED?

Bipole grouping cells can do both



Collinear cooperation and orientational competition

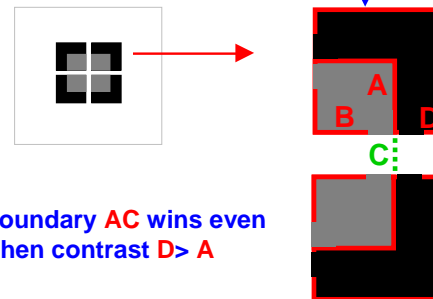
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SAME PROBLEM IN NEON SPREADING

Boundaries



Boundary **AC** wins even when contrast $D > A$

Like-polarity competition between **B** and **D** allows boundary **AC** to win.

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SAME PROBLEM IN BLOCKED NEON

Boundaries

Non-neon

Boundary **BD** wins even when contrast $A > D$

Opposite-polarity **B** and **D** contrasts do **NOT** compete.

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SAME OCCULARITY OF CONTRAST CAN INDUCE NEON

Neon Spreading

L R

No Neon Spreading

L R

Takeichi, Shimojo and Watanabe, 1992

Explanation: In the No Neon case, different ocularity inputs bypass the monocular polarity-specific competition in V1

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ILLUSORY CONTOUR FORMATION IS BINOCULARLY DRIVEN

Formation of illusory contours does not need inducers to have the same ocularity

L R

Takeichi, Shimojo and Watanabe, 1992

Layer 2/3 bipole grouping cells in V2 are binocular

V2 2/3

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ATTENTION MAKES EITHER BOUNDARY STRONGER

Before attention

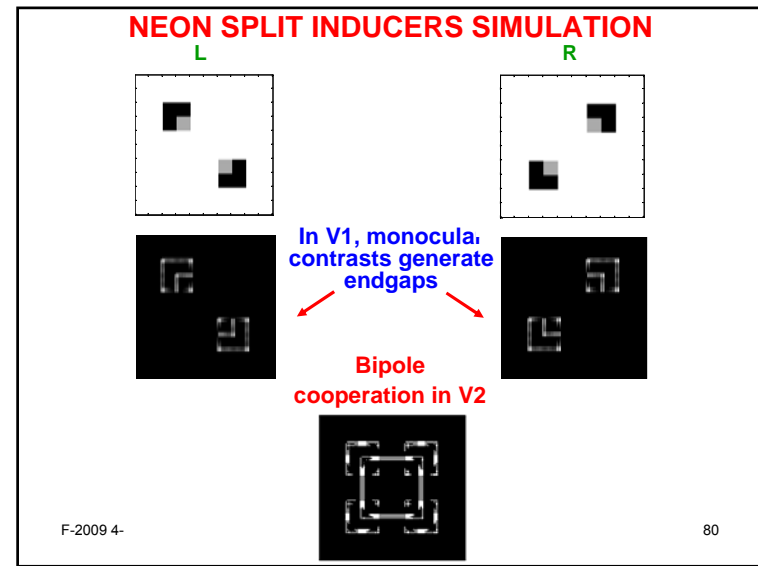
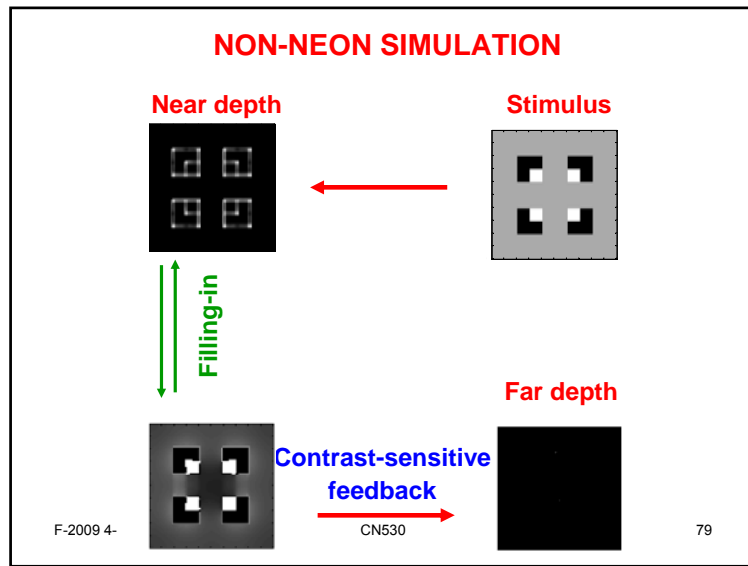
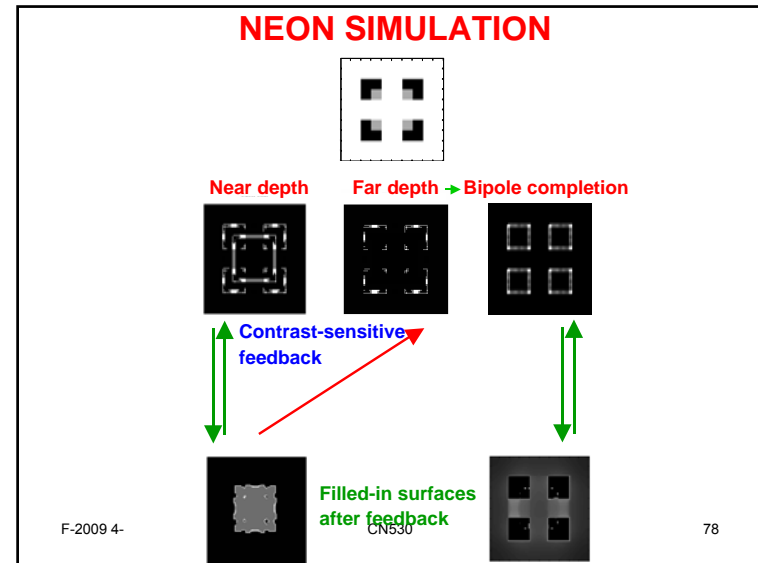
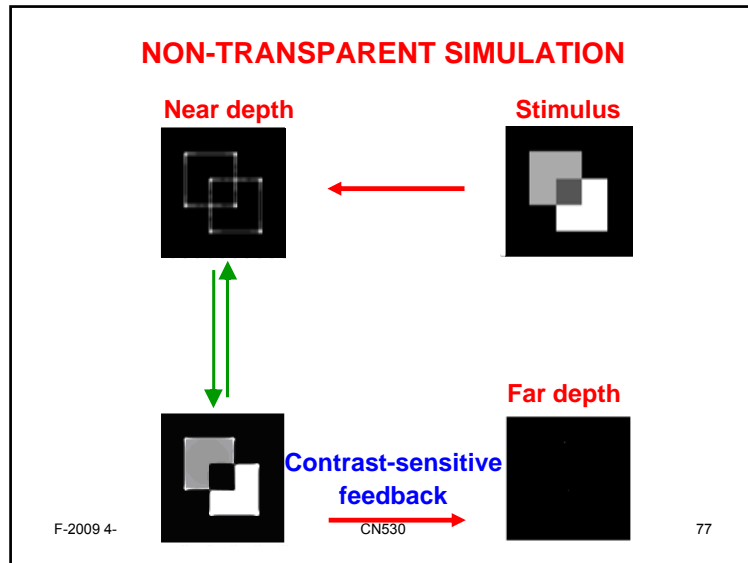
After attention

Attentional feedback

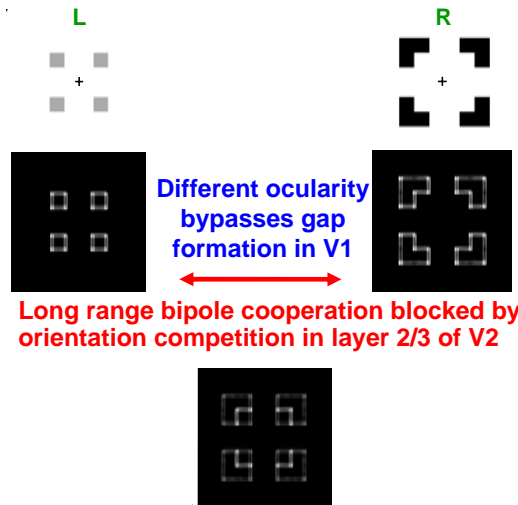
Attentional feedback activates layer 6 of V1

4 6

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NON-NEON CASE, SPLIT CONTRAST SIMULATION



CONCLUSION

1. Transparency and Neon color spreading data uncover some constraints on depth stratification
2. Monocular same-polarity competition explains the contrast relation role on depth stratification
3. This same polarity competition is implemented in layer 6 to 4 connection of V1, where cells are mostly monocularly driven

4. Implementation of monocular same-polarity competition unifies

STRATIFICATION
TRANSPARENCY
NEON COLOR SPREADING
phenomena

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CONCLUSION

5. Monocular same-polarity competition is consistent with model of inhibitory layer 4 development by Grossberg and Williamson (2001, Cerebral Cortex)

Question: What happens to layer 4 inhibition if animals reared in opposite polarity textures?

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