SPATIAL VISION

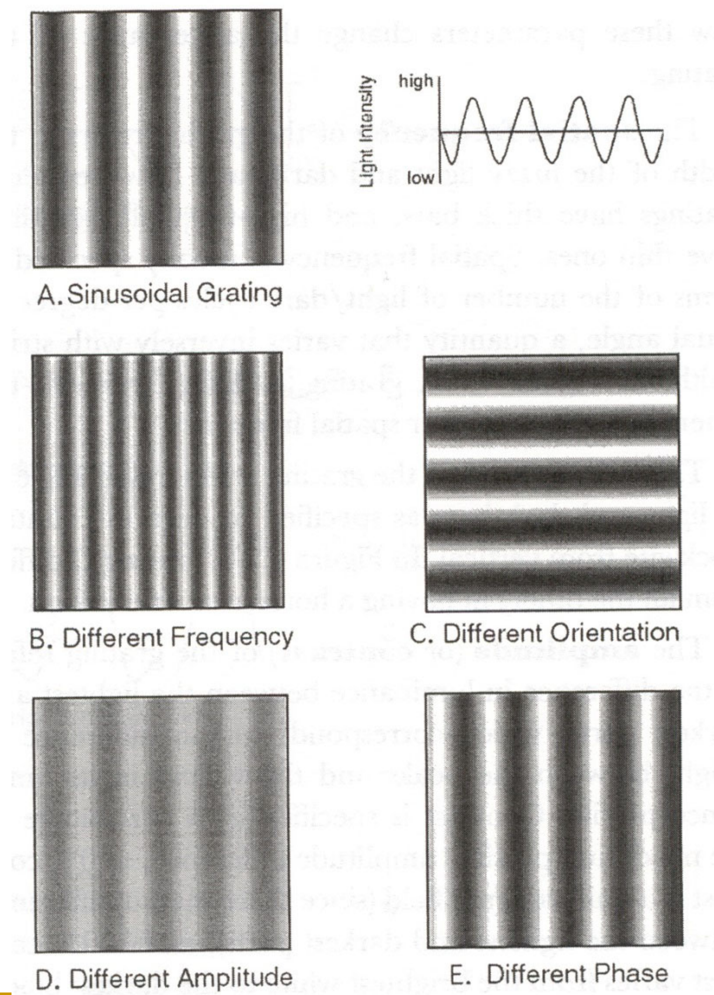
Visual Perception

Spatial Frequency Theory

- So far, we have considered, feature detection theory
- Recent development
  - Spatial Frequency Theory
  - The fundamental elements are spatial frequency elements
  - Does not preclude having feature detectors
- Spatial vision
  - No good convergence in physiology and psychophysics *yet*
    - Unlike color vision

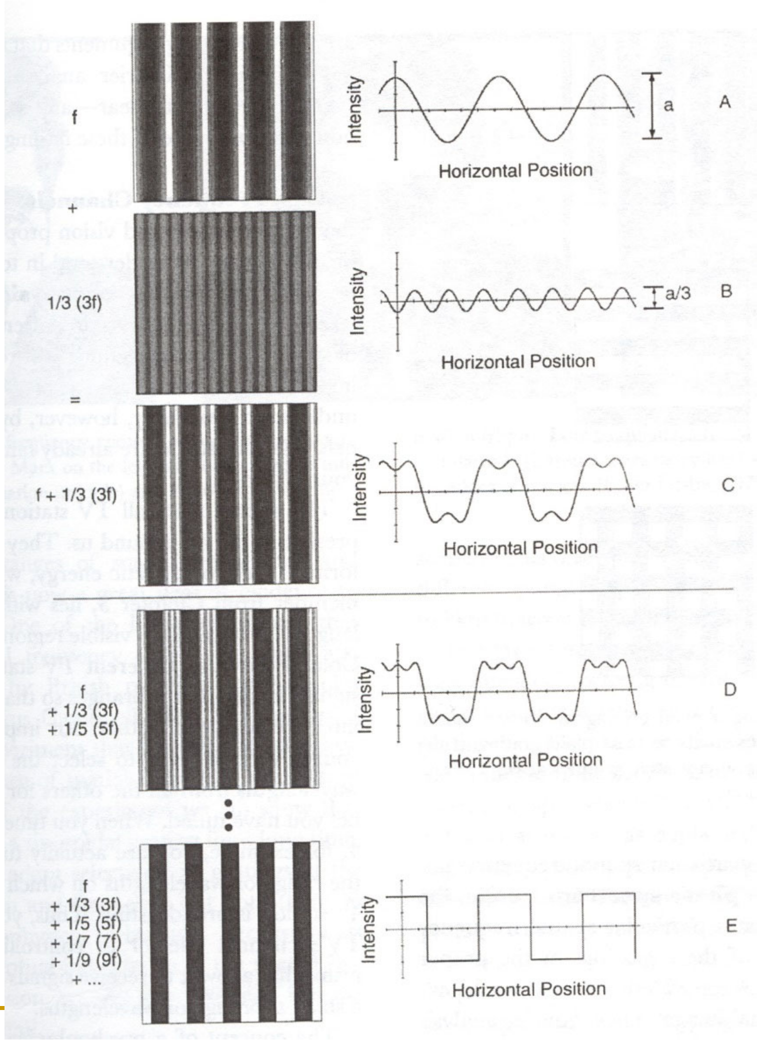
Gratings

- Images representing sine waves
  - Frequency
  - Orientation
  - Amplitude
  - Phase



Fourier Transform

- Any image can be expressed as a linear combination of a bunch of sine gratings of different *frequency* and *orientation*
  - Amplitude
  - Phase



Fourier Synthesis

- These component gratings can then be added together to create the original image back

Spatial Frequency Content

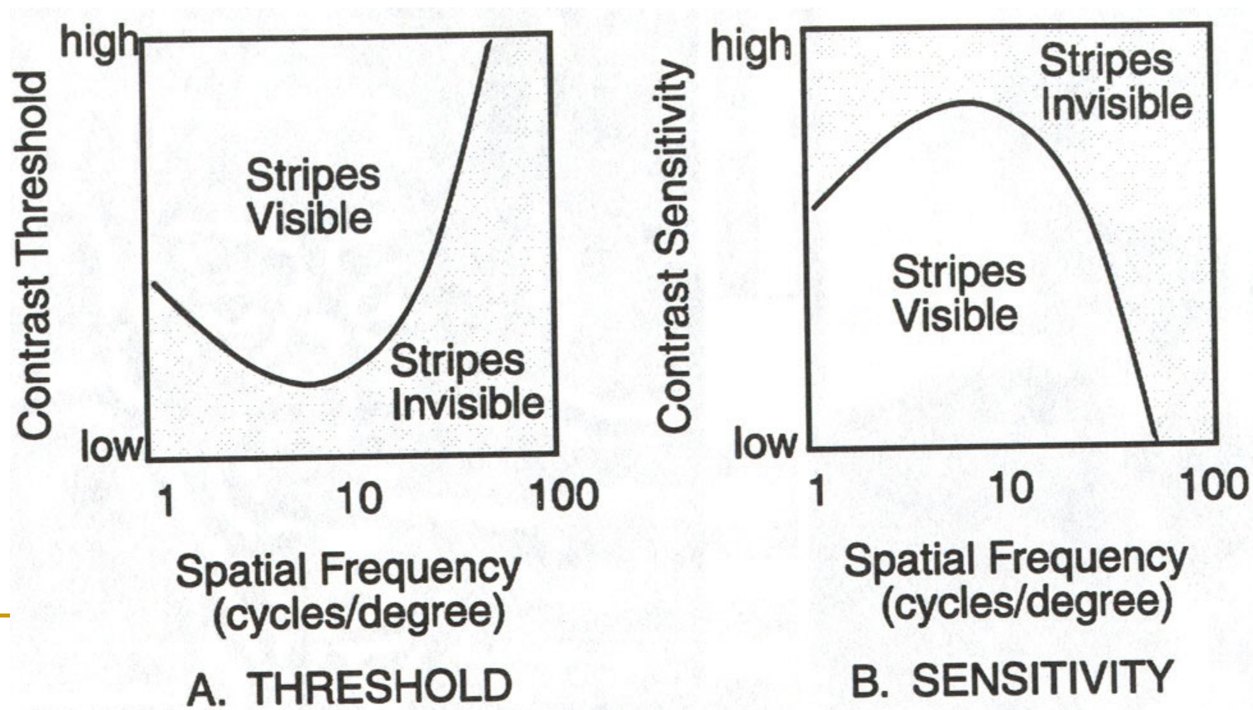
- Lower frequencies
  - Global pattern of light
- Higher frequencies
  - Feature details like edges

Contrast Sensitivity Function (CSF)

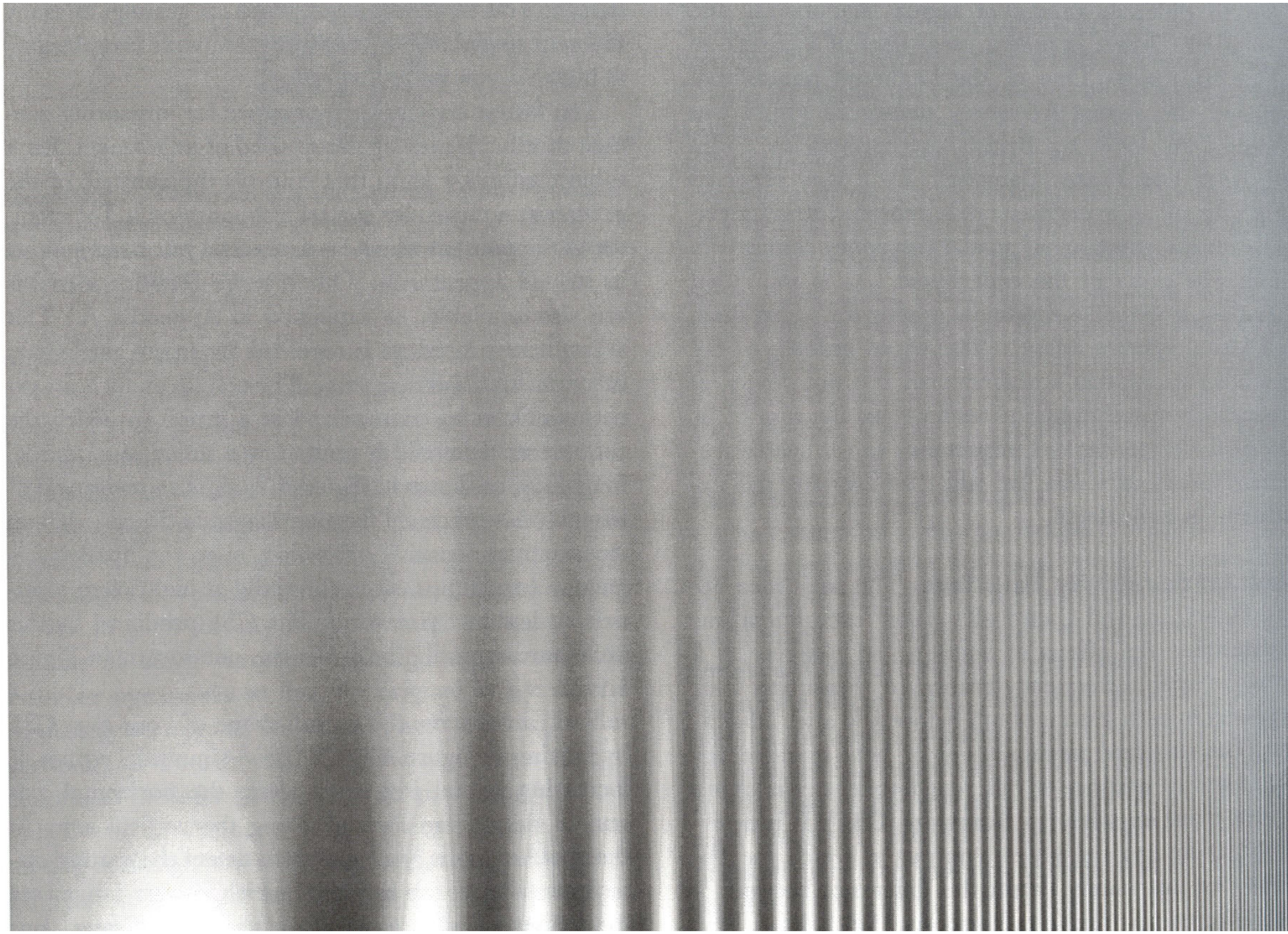
- Present a sine wave of particular frequency
- Start from 0 contrast and keep increasing contrast
- Note the contrast at which it becomes barely visible from an uniform gray field
- Defines the contrast threshold for that frequency
- Performed for a range of frequencies

Contrast Sensitivity Function (CSF)

- Minimum contrast required to *detect* a particular frequency
- Maximum sensitive at 4-5 cycles per degree



Testing Contrast Sensitivity

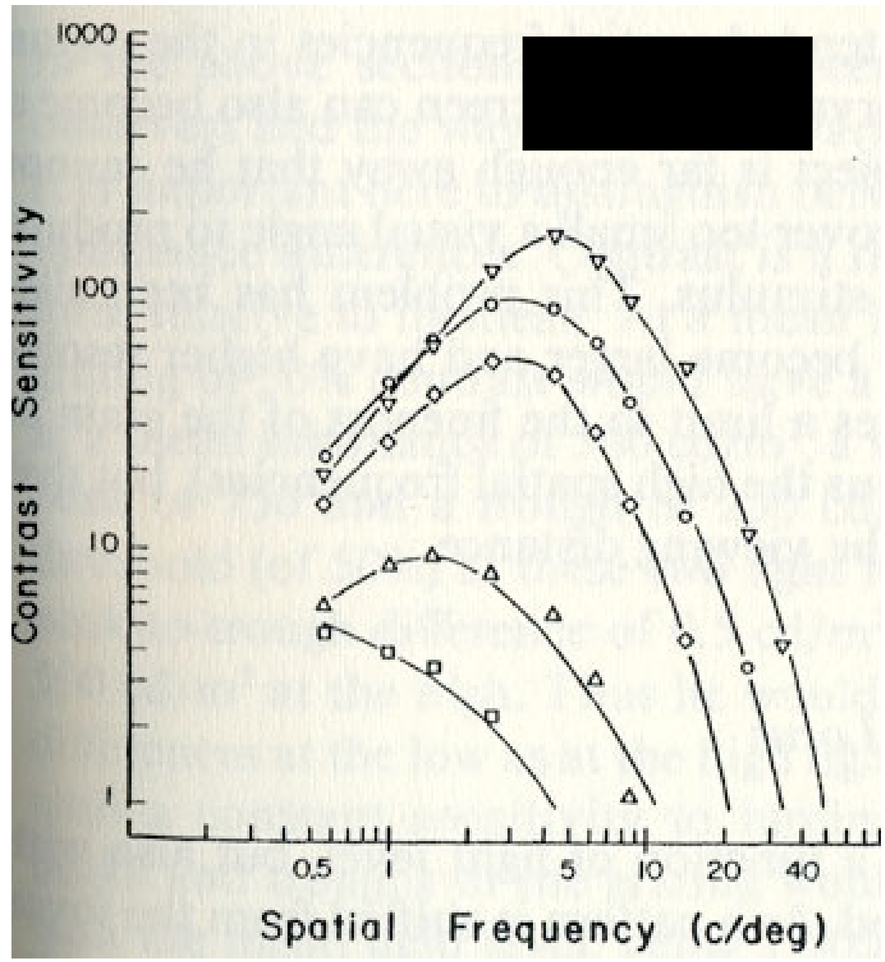


Calculating Cycles per Degree

- Distance of the subject from the screen in inch = d
- Resolution of the screen in pixels/inch = r
- No. of pixels per degree = $180/\pi*d*r$
- No of sine cycles in $180/\pi*d*r$ pixels tells the number of cycles per degree

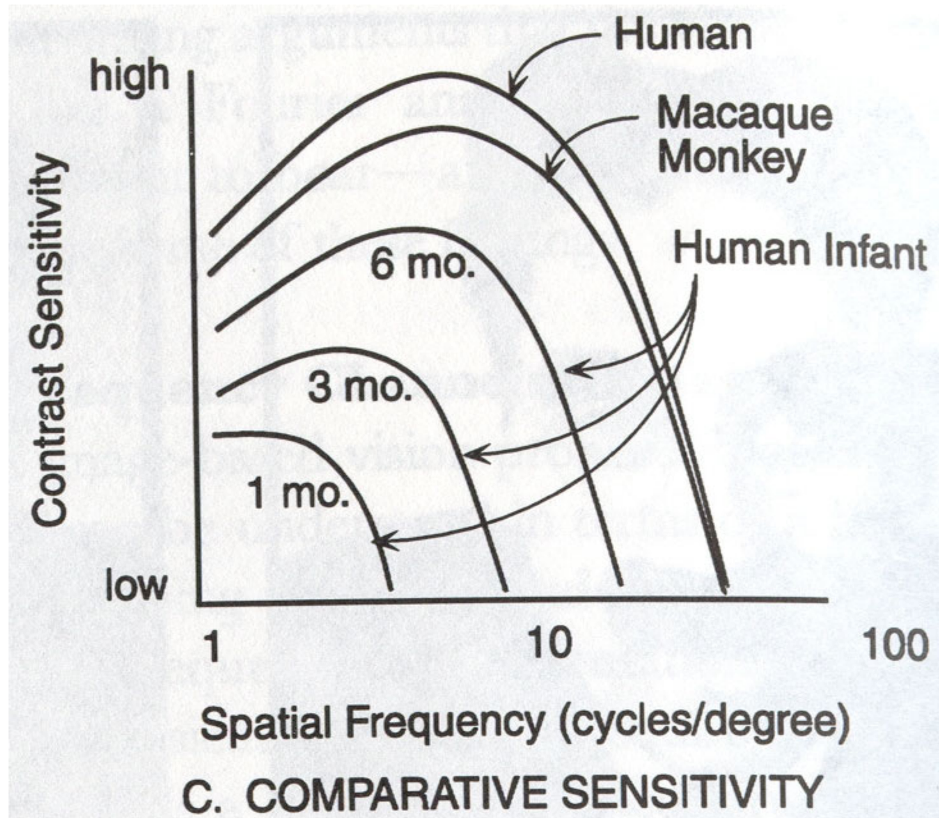
Changes with Illuminantion

- Sensitivity decreases with dark
  - Especially in high frequency regions
  - Lower visual acuity in dark
- The peak sensitivity occurs at lower frequencies
  - 5 to 2 cycles/degree

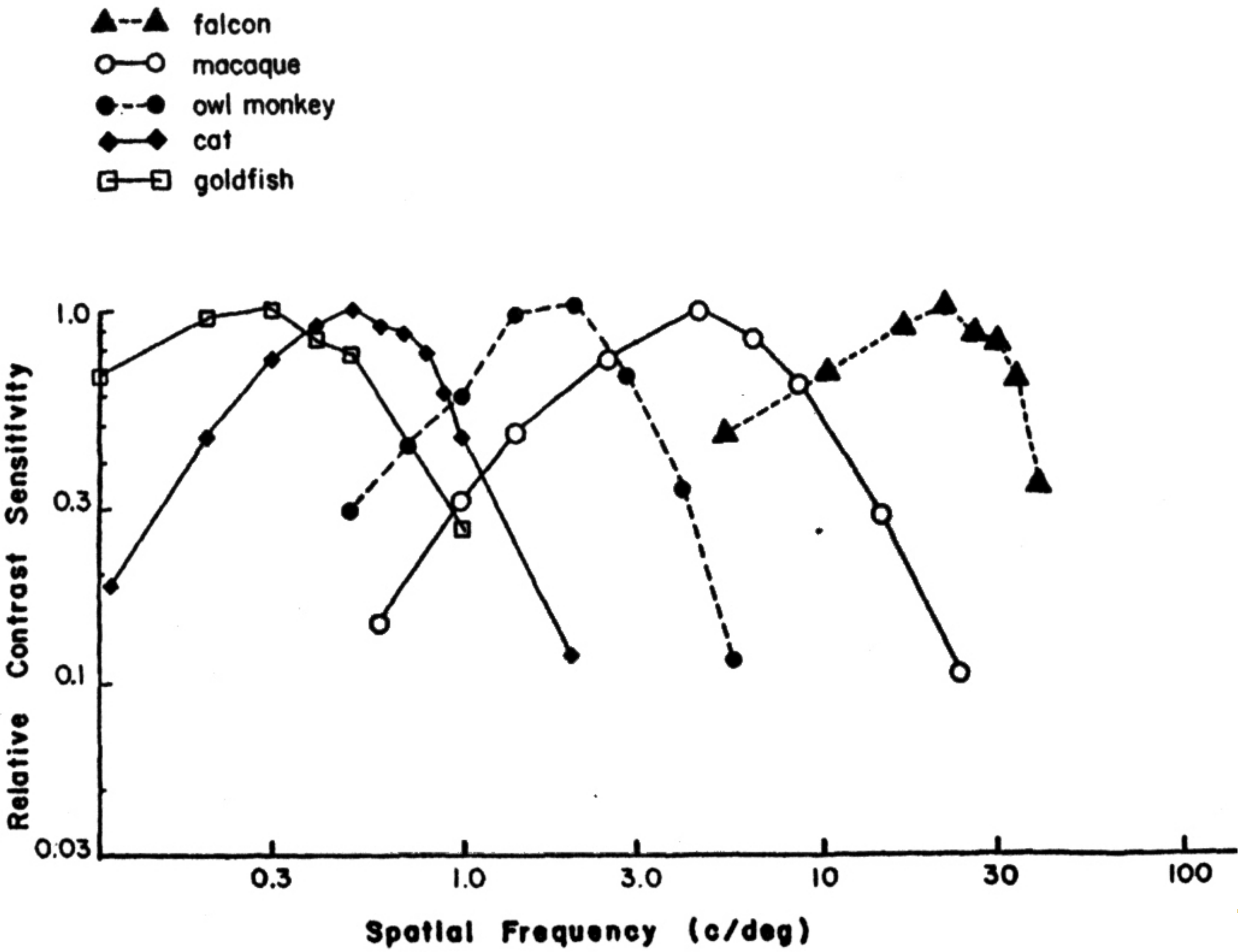


Development with Age

- Not great for babies
  - Infants cannot recognize people
- Monkeys and macaque have similar CSF as humans

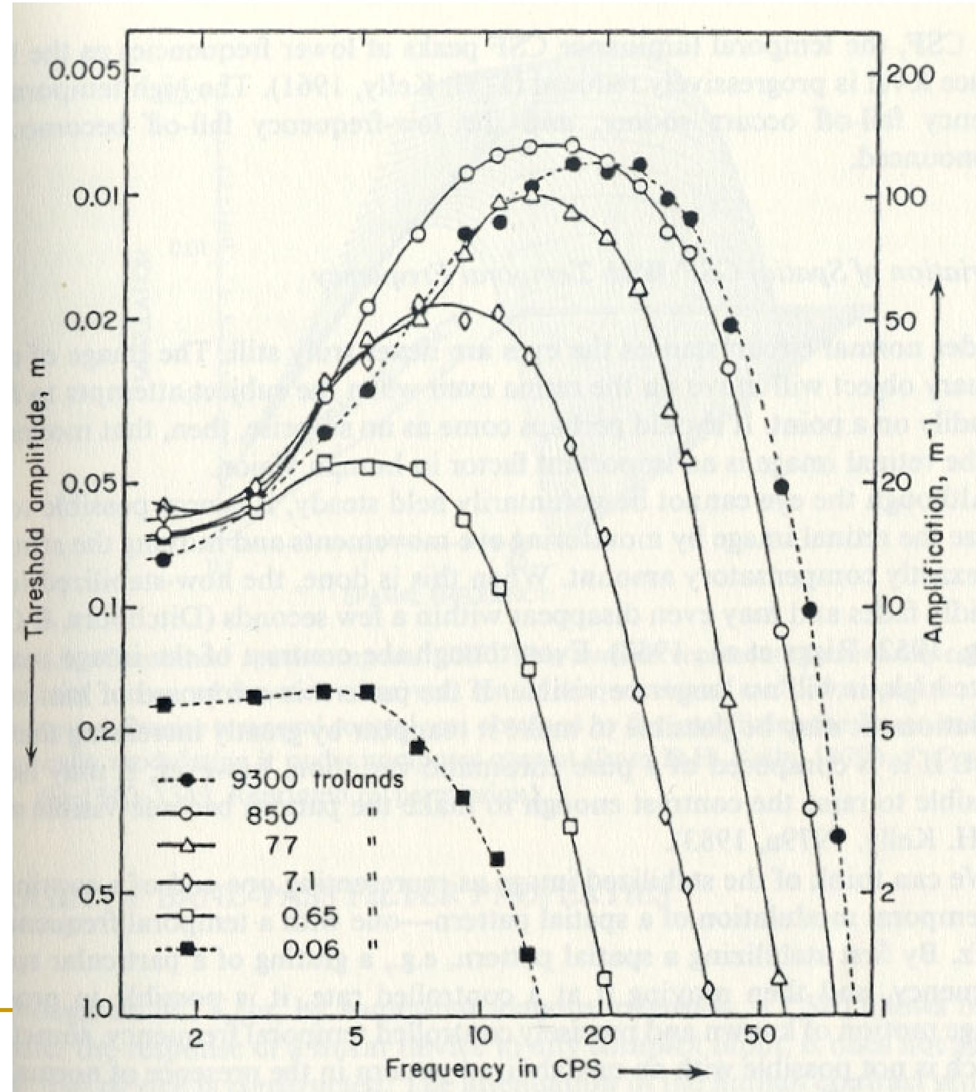


Development with Evolution



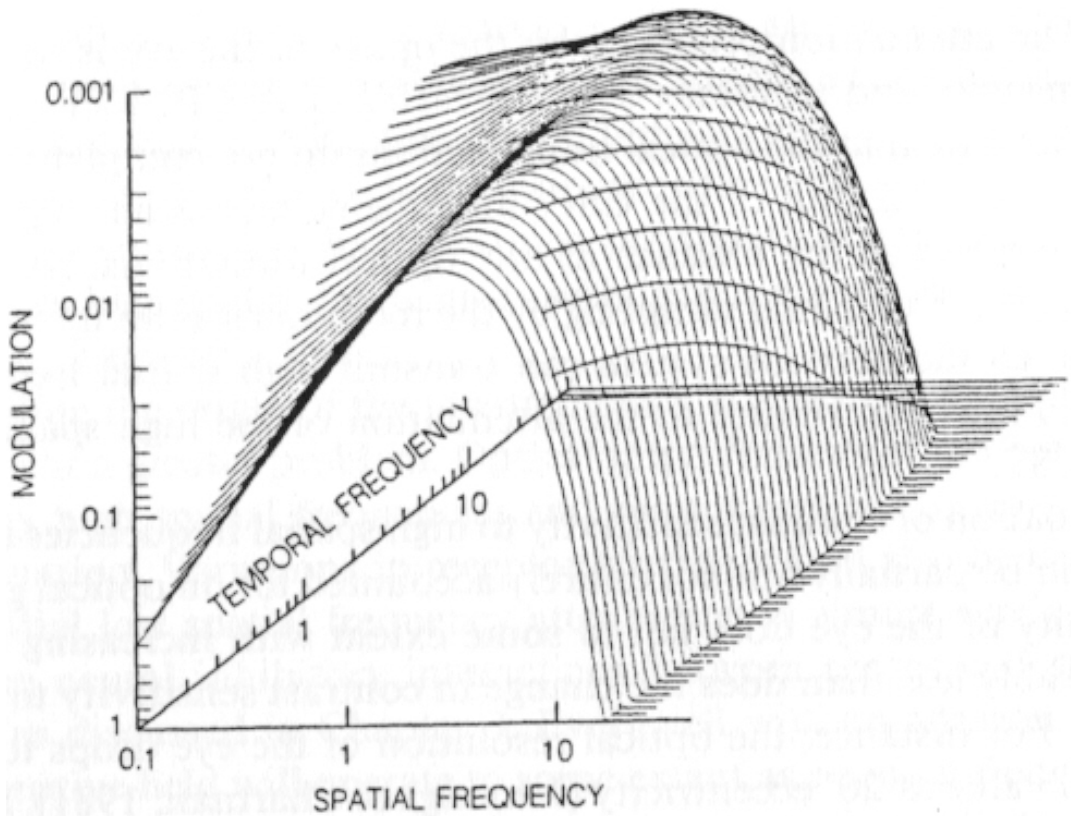
Temporal Contrast Sensitivity

- Present image of flat fields temporally varying in intensity like a sine wave
- If the flicker is detectable
- Cycles per second



CSF and filters

- Both spatial and temporal CSF act as band pass filters
- How do they interact?
  - At higher temporal frequency, acts as low pass filter

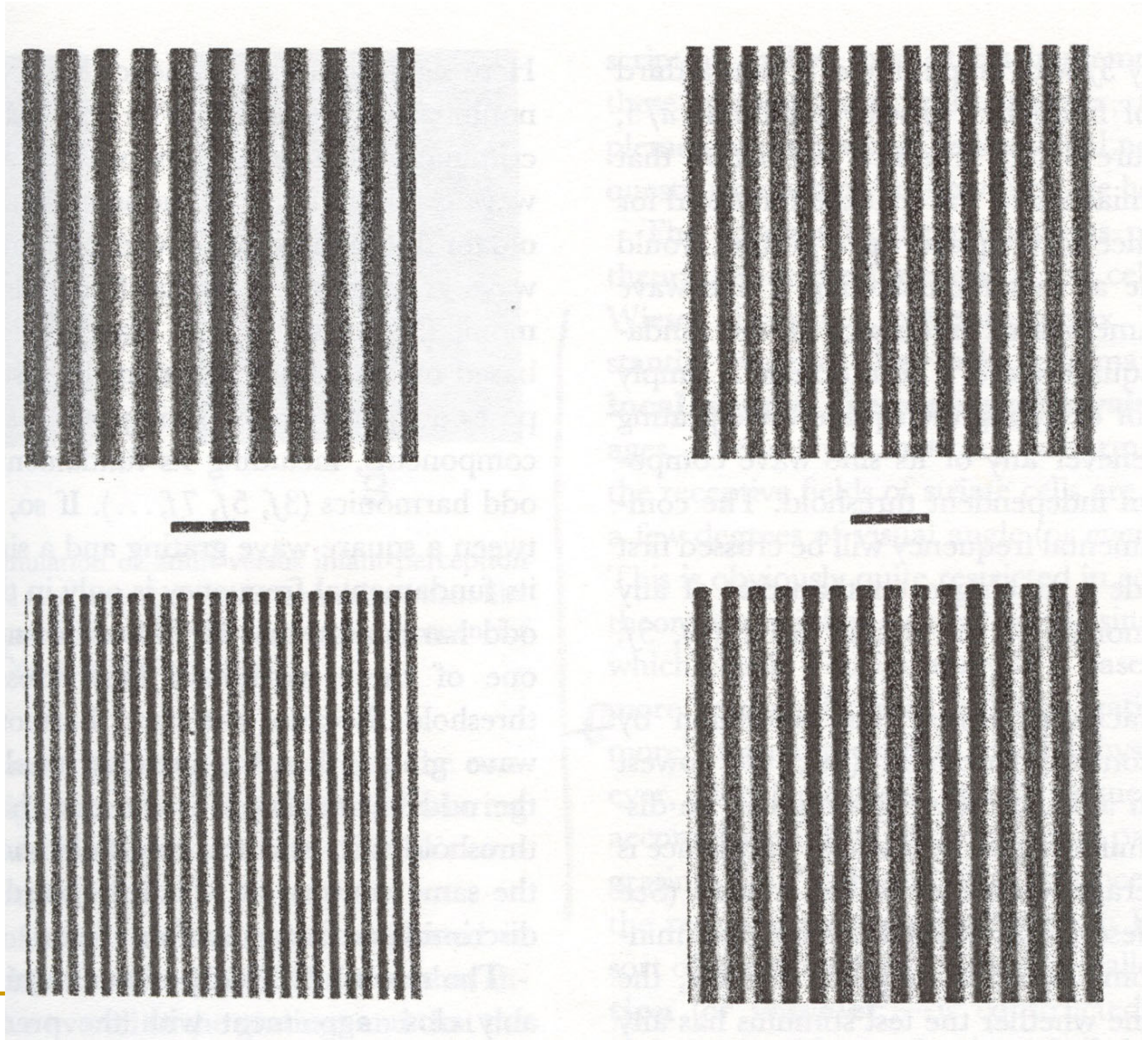


How does this help us?

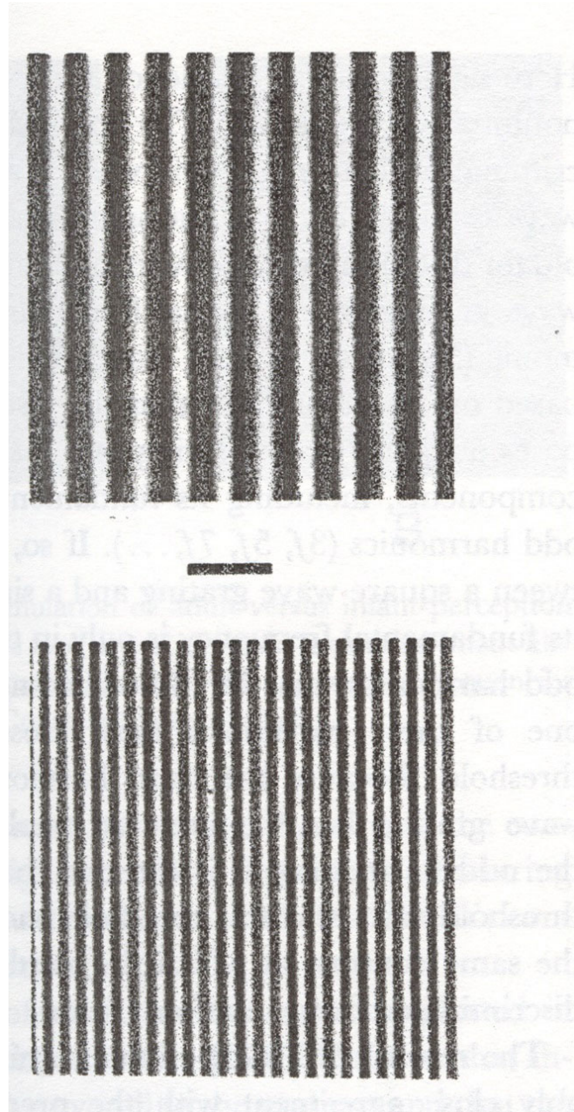
- Detecting objects versus illumination
  - Illumination changes are low frequency
    - Both in space and time
      - Morning to day to night
      - Changes over regions slowly
  - Can phase out illumination and be more sensitive to reflectance
- Insensitive to afterimages
  - Usually blurred low frequency ones

Selective Adaptation of Channels

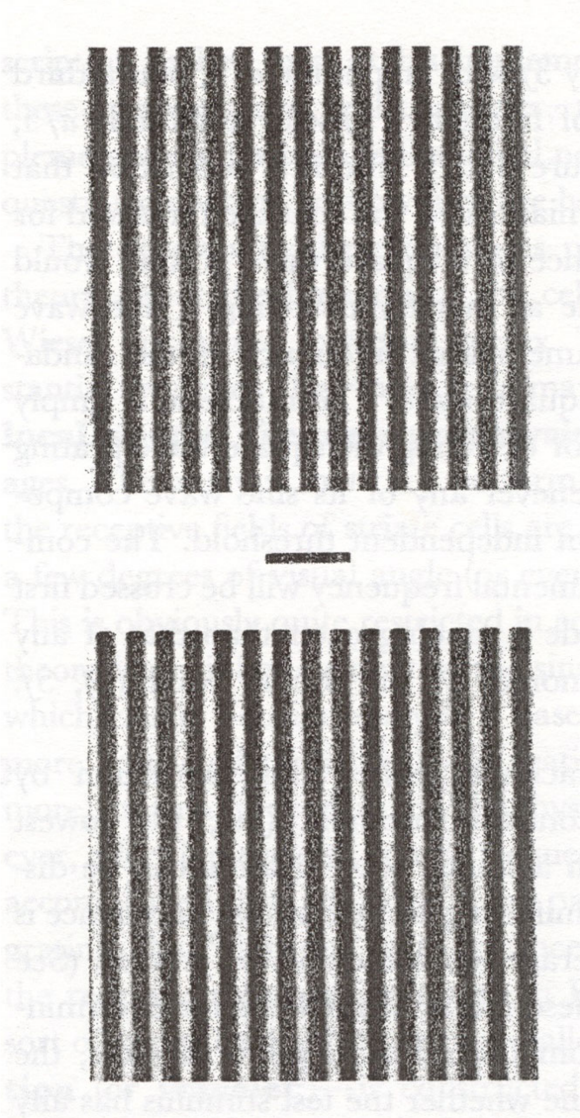
- Adaptation to certain ranges of frequencies
- Selective adaptation aftereffects



Experiment

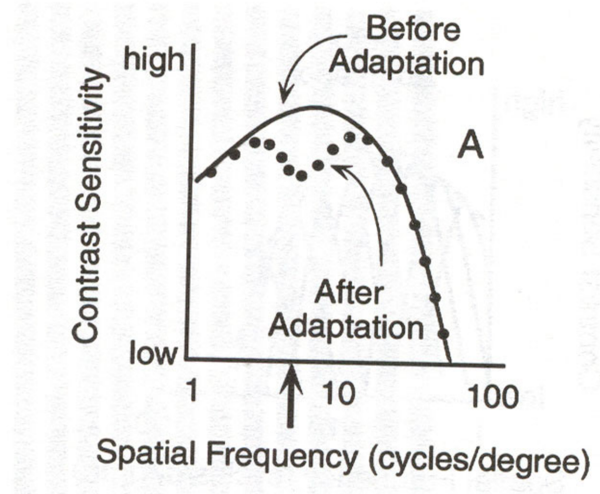


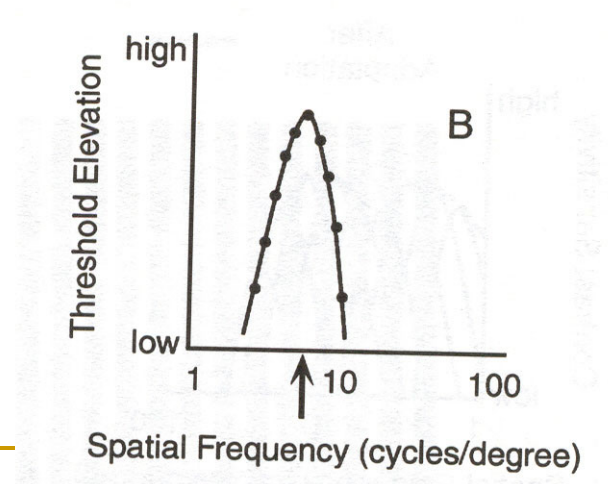
Experiment



Selective Adaptation of Channels

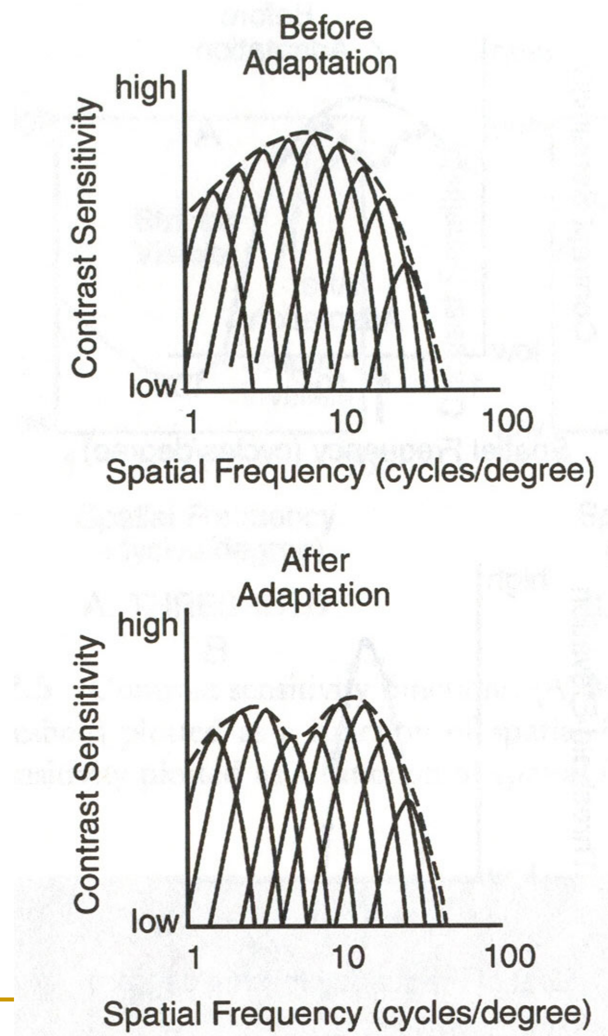
- CSF changes before and after adaptation
- Subtraction from the original CSF gives the response of the cells that are adapting





Selective Adaptation of Channels

- Multiple channels that adapt to different ranges of frequencies

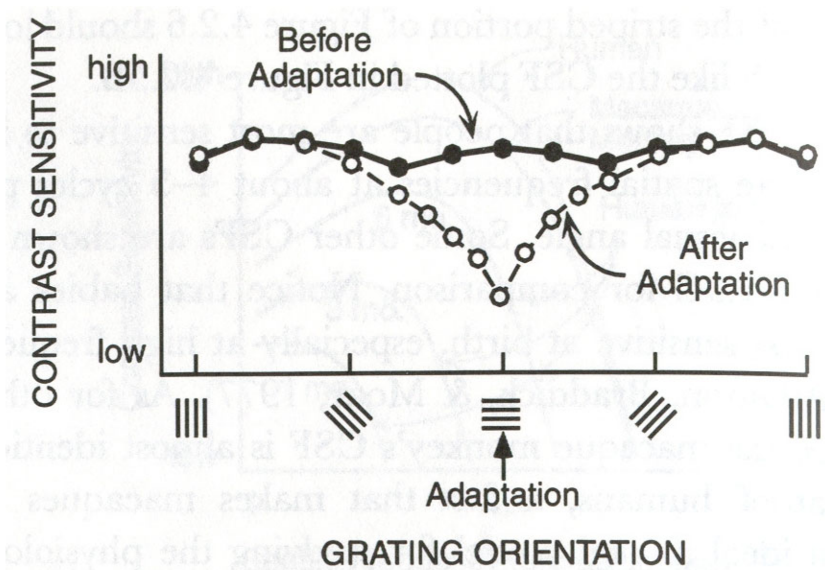


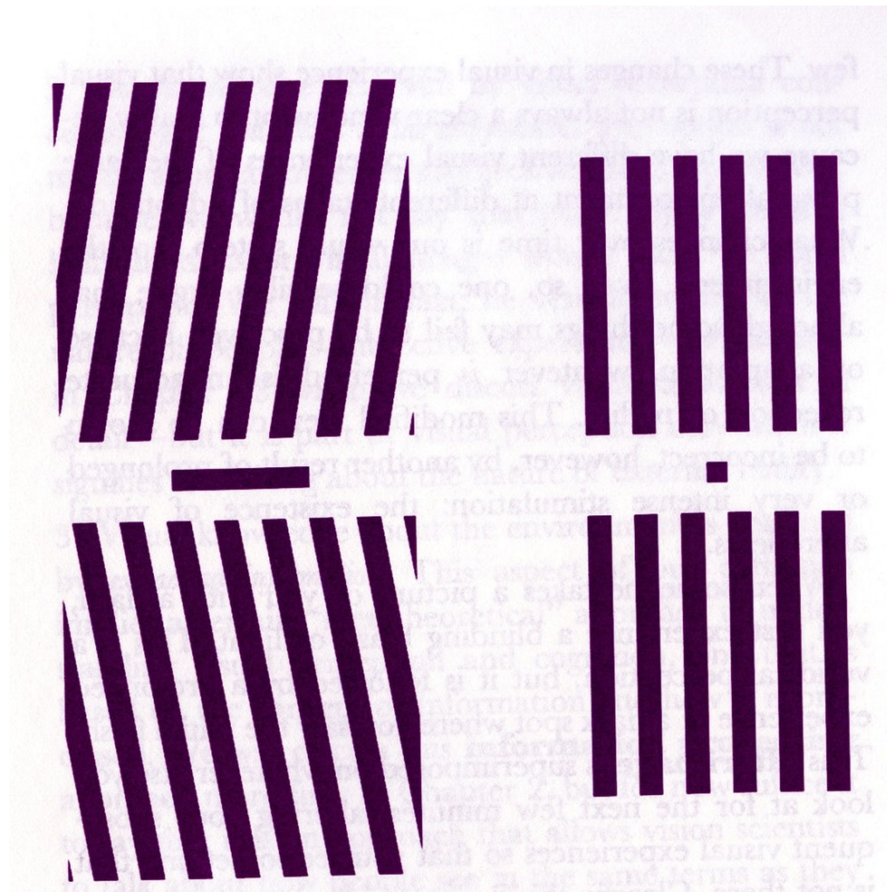
Spatial Frequency Theory

- Each channel sensitive to particular range of frequencies and orientations
- Can overlap with each other
- Similar to the color primaries
- Acts like band pass filters

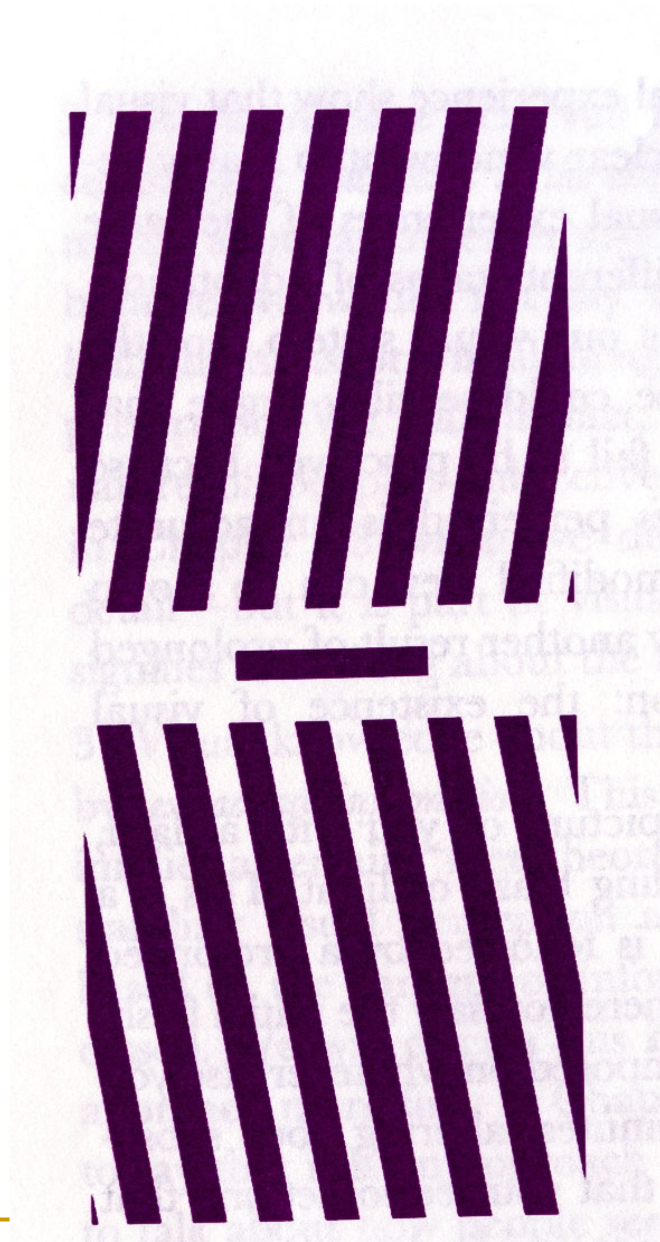
Selective Adaptation to Orientations

- Similarly, for orientation
- Orientation adaptation aftereffects

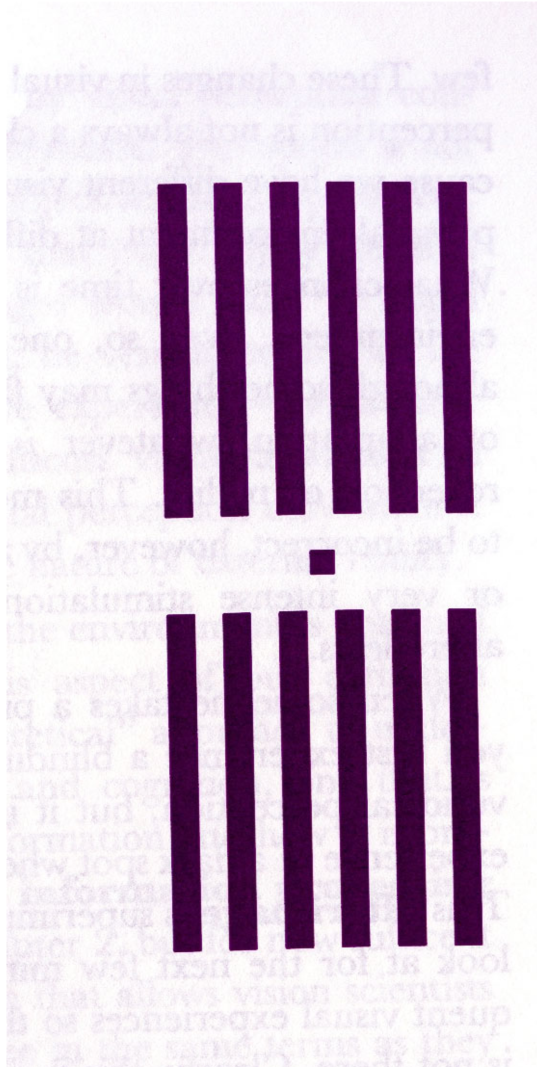




Experiment



Experiment

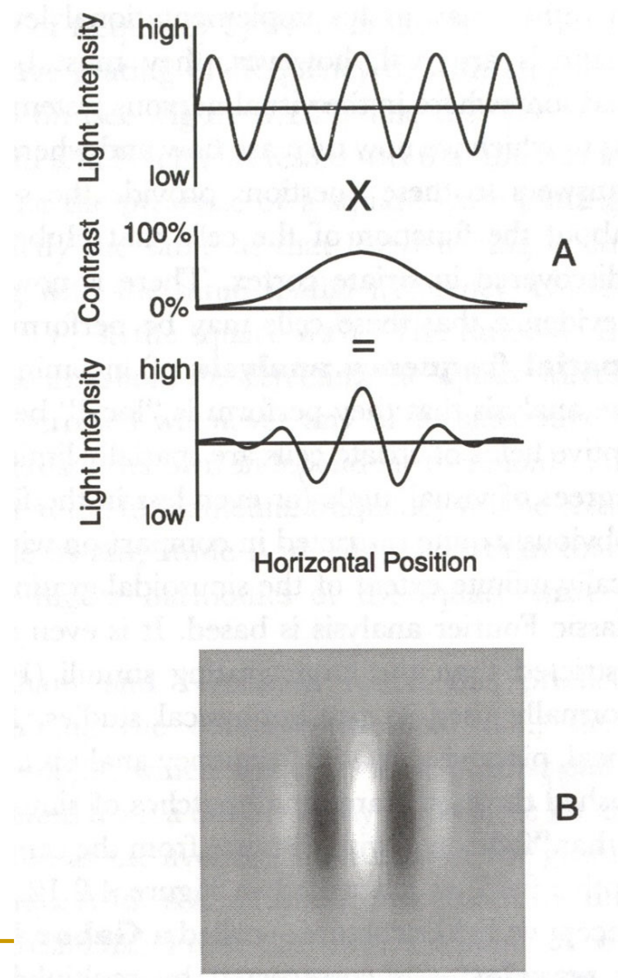


Further Support

- Checking the threshold for square and sine grating of same frequency (above 4-5 cycles per degree)
- Should be same
  - Square wave made of many sine waves
  - Will be visible as soon as one of the sine waves are visible
  - The threshold for the higher sine waves are lower

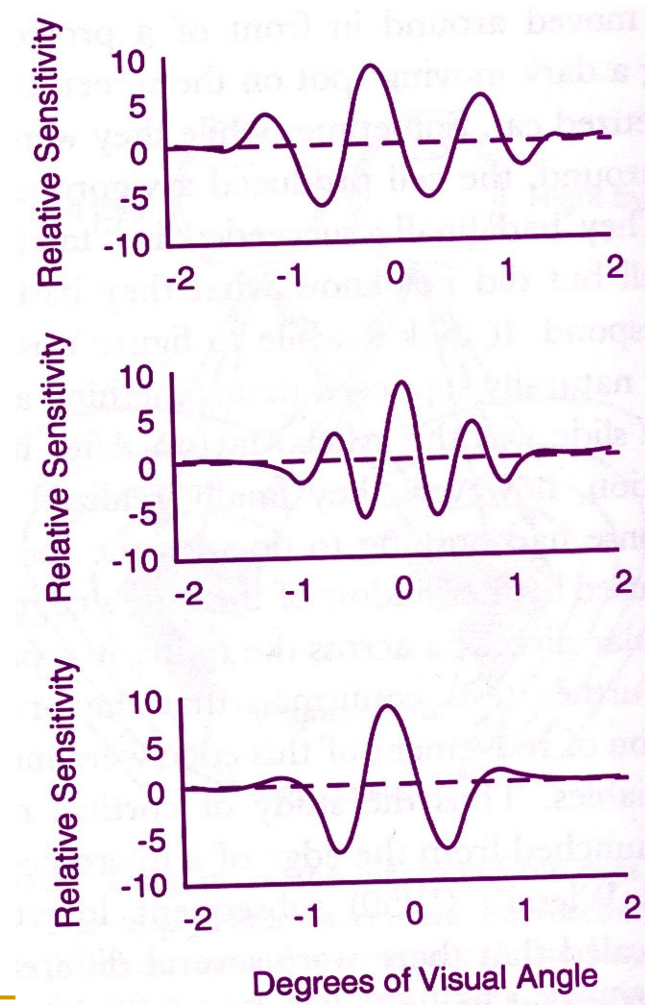
Physiological Support

- Infinite sine waves
- Eye has finite receptive fields
- Local piecewise frequency analysis
  - Small patches of sine waves that fade out
  - Gabor Functions
    - Multiplying sine waves with a gaussian



Physiological Support

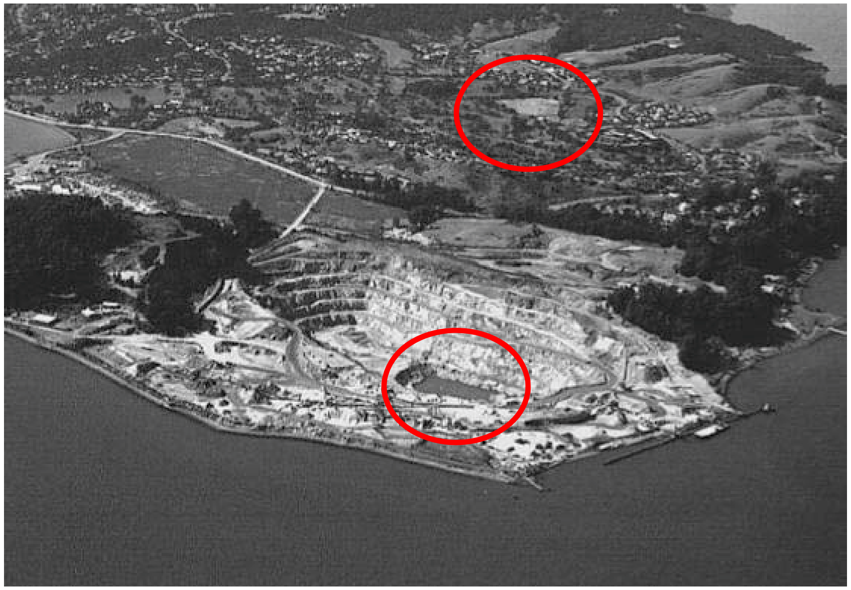
- Gabor Functions
  - Cells with such response found in the simple cells of visual cortex



Filters

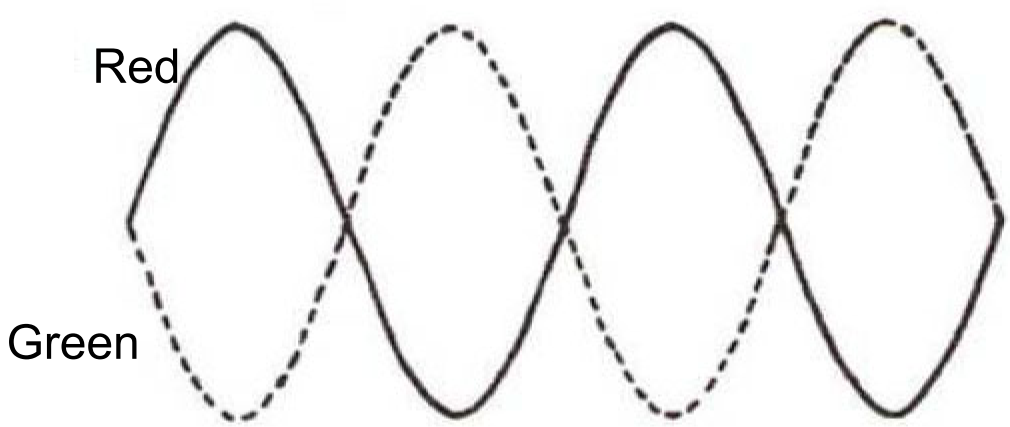
- Low pass filters
  - Blocks high frequencies
  - Image blurring
- Band pass filters
  - Blocks both high and low frequencies allowing only medium ones
- High Pass filter
  - Blocks low frequencies
  - Edge detection

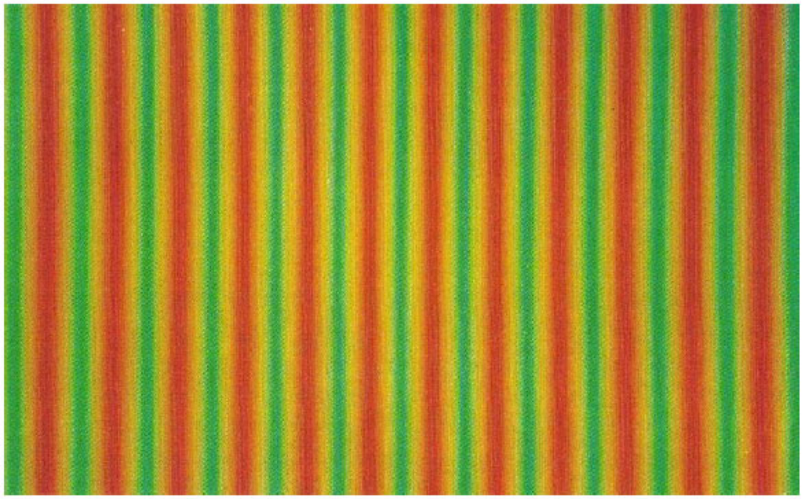
Role of Color

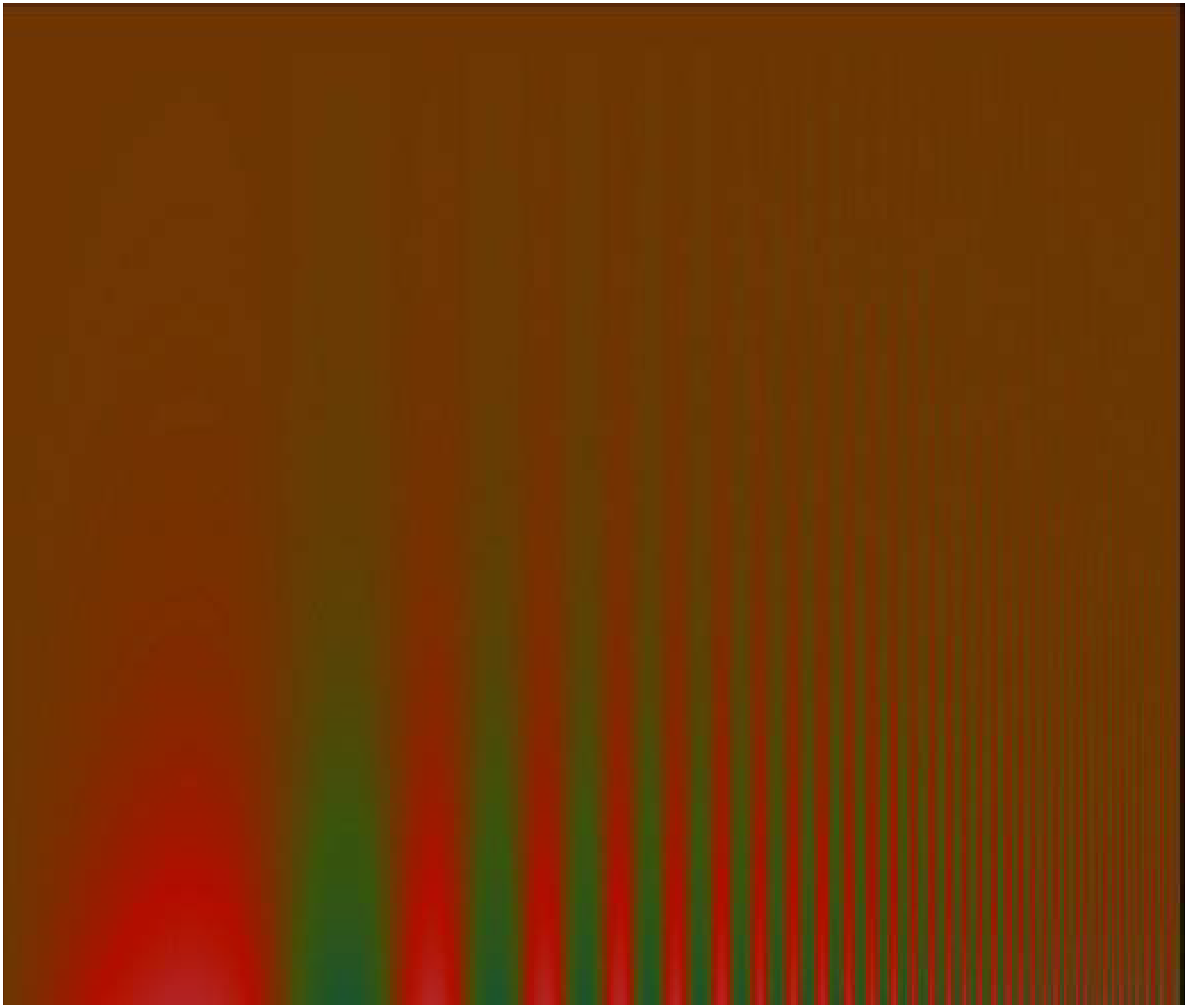


Studying Chromatic Contrast

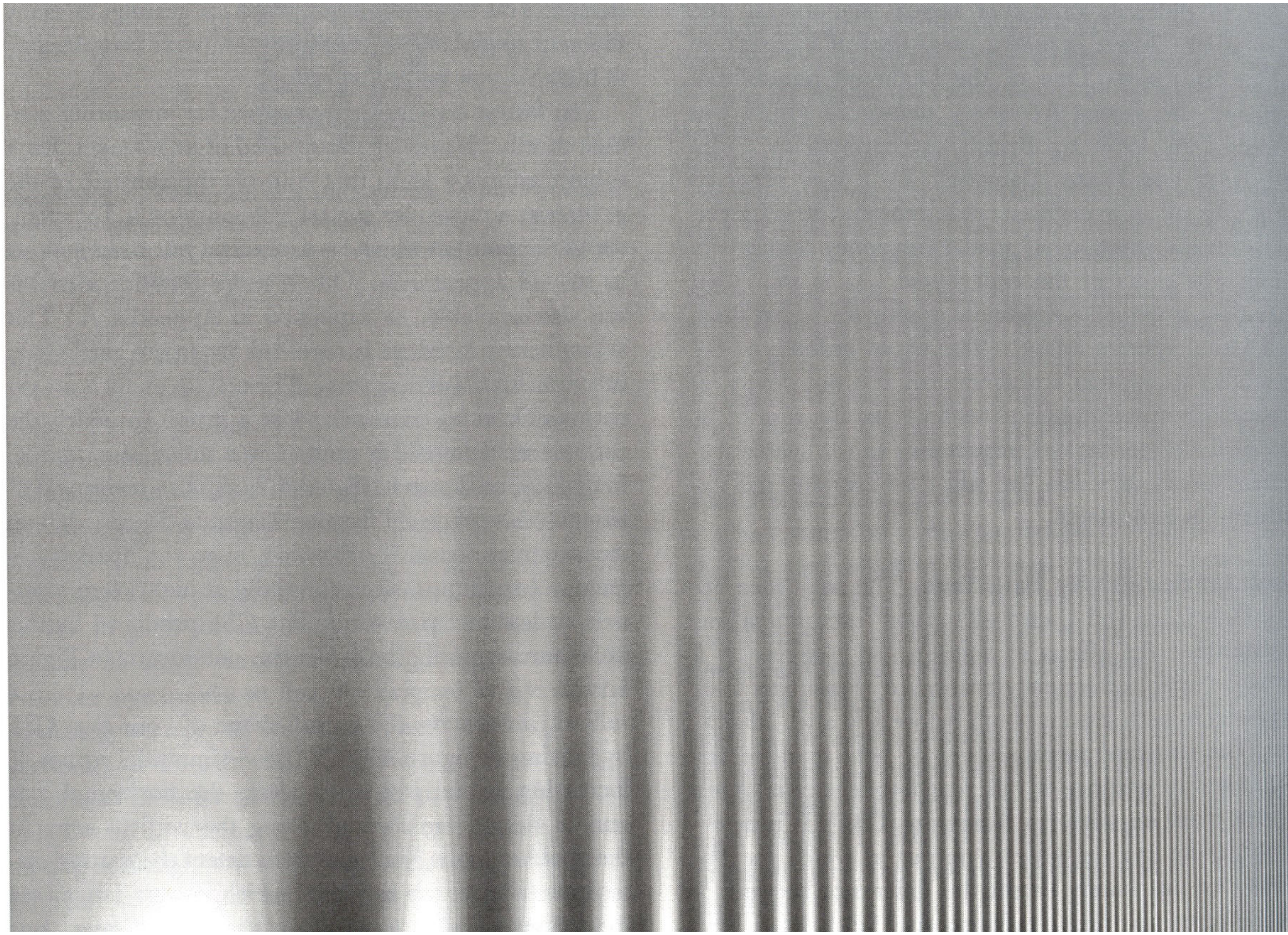
- Adding iso-chrominance gratings
  - Out of phase creates iso-luminance color gratings





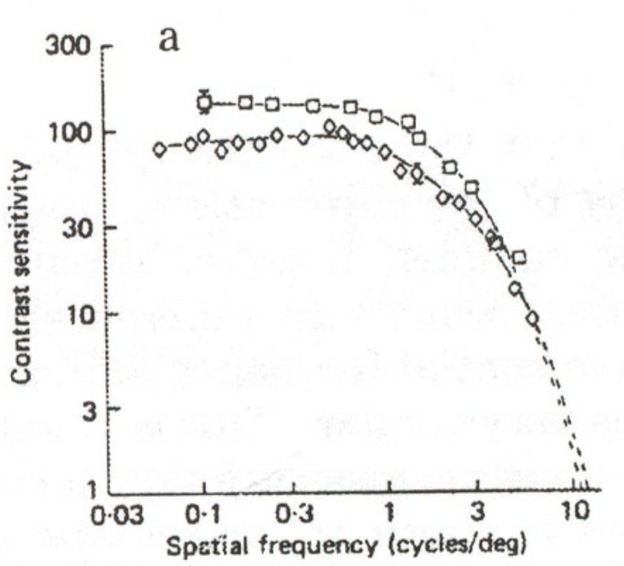


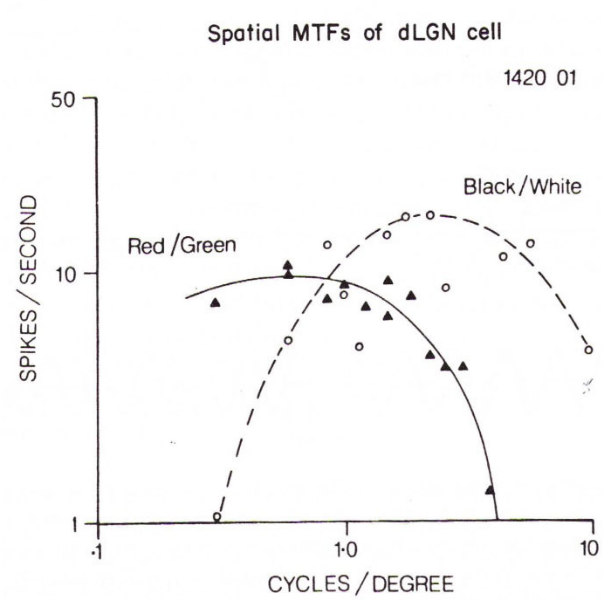
Testing Contrast Sensitivity



Chromatic Contrast

- Gratings
  - Red-Green (602, 526nm)
  - Blue-Yellow (470, 577nm)
- Summation of band responses





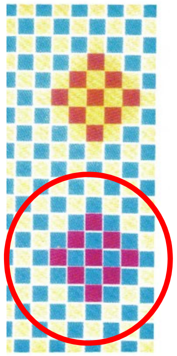
Comparison

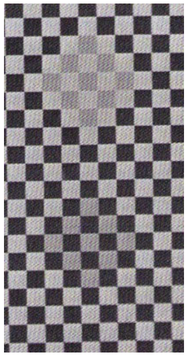
- Low pass filter rather than bandpass filter
- Sensitivity is lower
  - More sensitive to luminance change than to chrominance change
- High frequency cut-off is 11 cycles per degree rather than 30 cycles per degree
  - Color acuity is lower than luminance acuity

Similitude

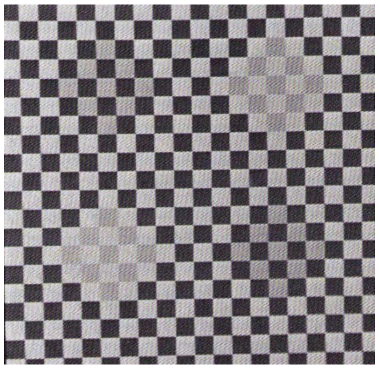
- Similarity of a pattern with its background

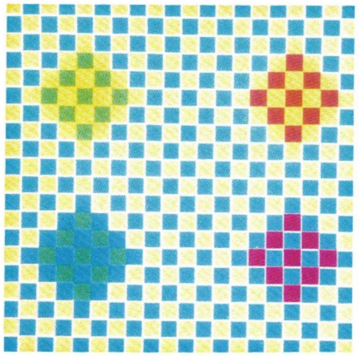
Patterns	Low Spatial frequencies	Mid Spatial frequencies	High Spatial frequencies	Very high Spatial frequencies
Luminance patterns	_	Contrast	Contrast	Similitude
Color patterns	Contrast	Similitude	_	_





- Which one stands out more?
- Exactly same red
  - More similitude in color
  - Perception driven by similitude
  - Top – Red similar to yellow (towards orange)
  - Bottom – Red similar to blue (towards purple)
- Same effect for green
- But for luminance, directed by contrast



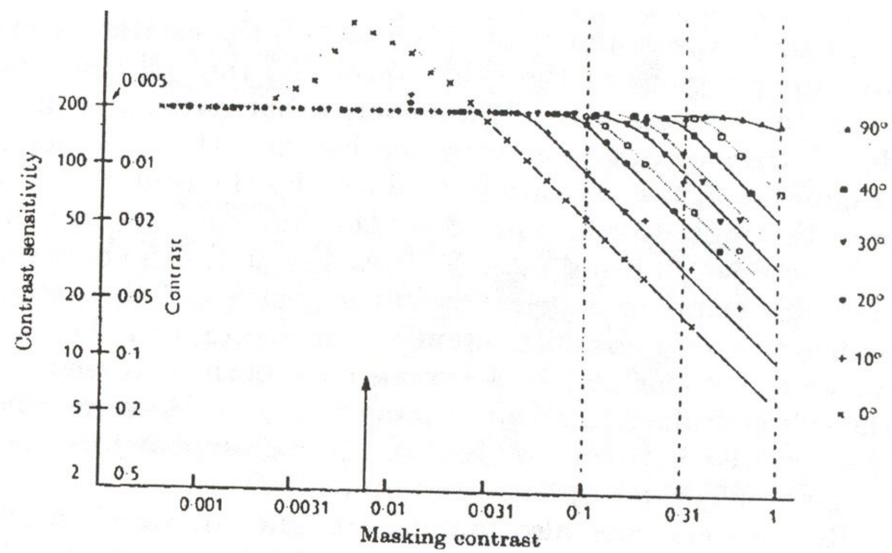


Visual Masking

- Certain frequencies and orientation mask others perceptually
- Experiments
  - Test grating presented on a masking grating
  - At different contrast of the masking grating
  - Measure the CSF for the test grating

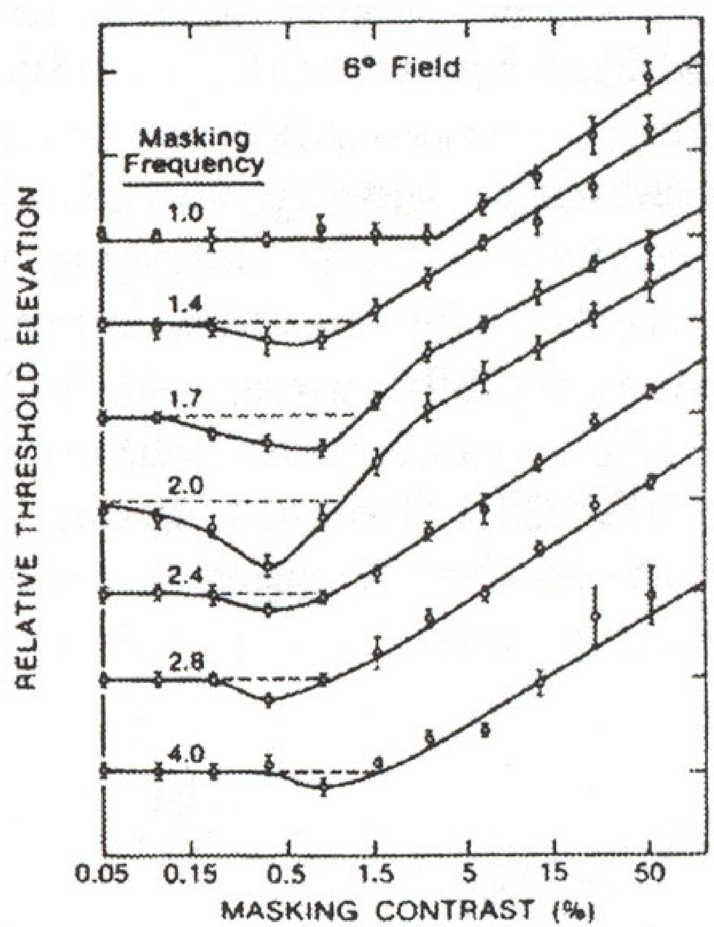
Orientation

- Test: Vertical 2 cycles/deg
- Contrast sensitivity with different mask contrast
- For different orientation masking grating
- As difference in angle increases, masking effect reduces
- Masking more effective at higher contrasts
- Facilitation at low contrast for similar orientation

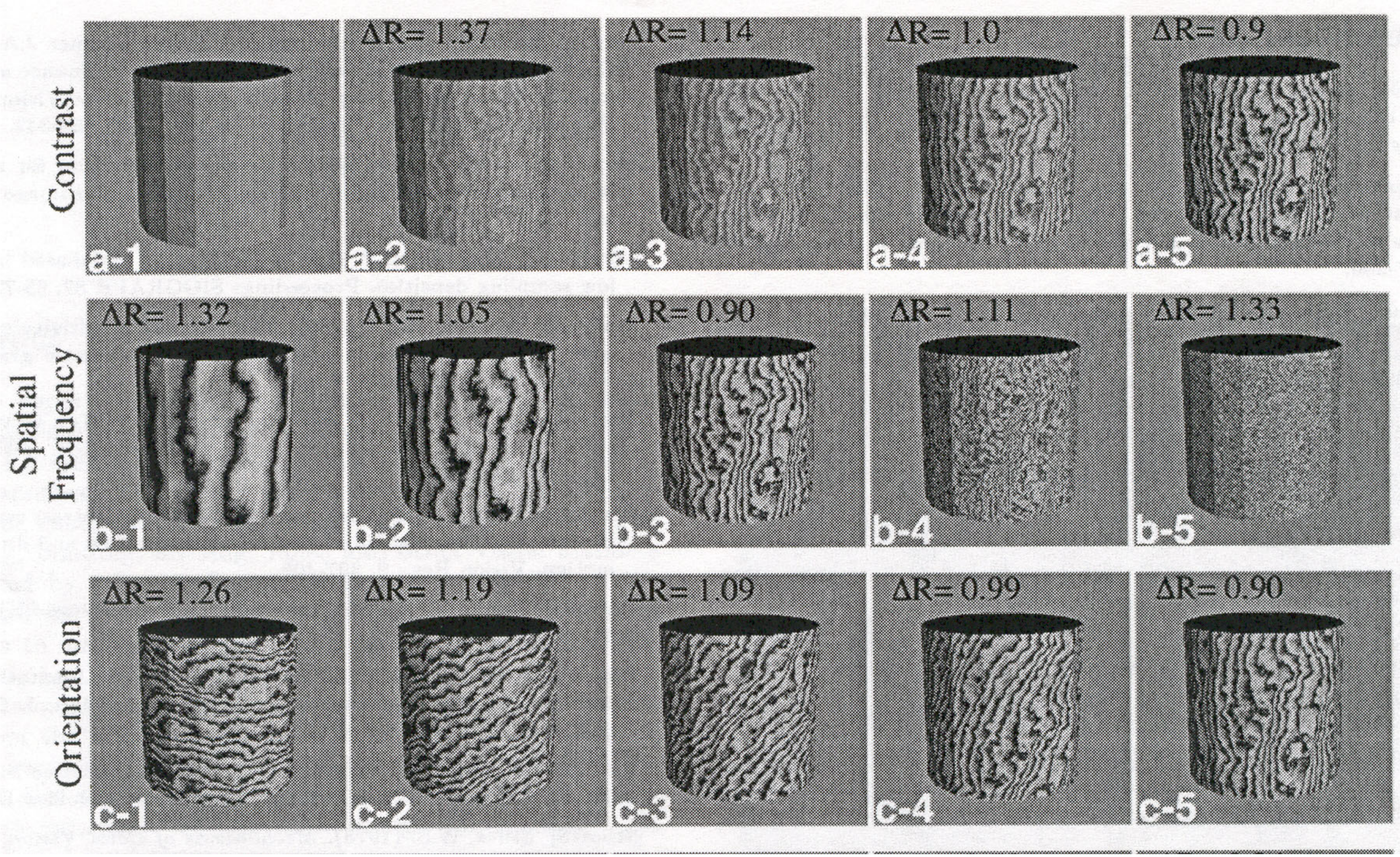


Spatial Frequency

- Similar plot but with threshold
- Test frequency: 2 cycles/deg
- Masking frequency: 1-4 cycles/deg
- Low contrast creates facilitation
  - Threshold decreases (more sensitive)
- High contrast creates masking
  - Threshold increases (less sensitive)



Effects



Contrast
ΔR= 1.37
ΔR= 1.14
ΔR= 1.0
ΔR= 0.9
a-1
a-2
a-3
a-4
a-5
Spatial Frequency
ΔR= 1.32
ΔR= 1.05
ΔR= 0.90
ΔR= 1.11
ΔR= 1.33
b-1
b-2
b-3
b-4
b-5
Orientation
ΔR= 1.26
ΔR= 1.19
ΔR= 1.09
ΔR= 0.99
ΔR= 0.90
c-1
c-2
c-3
c-4
c-5