POVS
Basic Vision Science Core
Spatial Vision III: Channels & Vision
CSF
What is a “Channel”?

- CSF represents the envelope of many narrowly tuned channels.
- A channel is a filtering mechanism, something which passes some, but not all, of the information that may impinge upon it.
Receptive Field (RF) Structure and SF Tuning

- Optimal responses occur for the SFs that match each neuron’s RF profile.
- Responses are reduced for higher SFs due to reduced excitation, and for lower SFs due to increased lateral inhibition.
Lateral Inhibition

- Retinal (and post-retinal) receptive fields (RFs) have antagonistic center-surround organization.
- E.g. on-center off-surround receptive field:

  + +
  + +
  - -
  - -
  - -
  - -
  - -
  + +

  + = excitation
  - = inhibition
Therefore, this is a “center-surround” receptive field with lateral inhibition.

$E+I$:

\[ + = \text{excitation} \\
\] 

\[ - = \text{inhibition} \]
Receptive fields have spontaneous firing activities.

Excitatory region (+): loves light. When a light is shone on it, firing rate increases.

The larger is the spot of light in the excitatory region, the higher is the firing rate.

When a spot of light is shone on the inhibitory region (-), firing rate decreases.
Psychophysical Evidence

1. Detection of patterns based on amplitude spectra.
2. Spatial frequency specific adaptation.
3. Spatial frequency specific aftereffects.
4. Spatial frequency selective masking.
5. Subthreshold summation.
Pattern-Detection Based on Amplitude Spectra

- The fundamental component of a squarewave is a sinewave of the same frequency but of $4/\pi$ times the amplitude of the squarewave.

- If the overall contrast of the pattern is the crucial variable, a sinewave and a squarewave grating should be detected at the same contrast.
Pattern-Detection Based on Amplitude Spectra

• If the patterns are being detected on the basis of the outputs of various parallel, narrow-band SF channels, the squarewave grating should be detectable at a lower pattern contrast.
Squarewave vs. Sinewave

Campbell & Robson (1968)

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Campbell & Robson (1968)
Squarewave vs. Sinewave

Campbell & Robson (1968)
Perceptual Discrimination

• At threshold a sinewave and a squarewave of the same fundamental frequency are perceptually indistinguishable.

• Only when the third harmonic of the squarewave reaches its own threshold do the two patterns become perceptually distinguishable.
Spatial Frequency Specific Adaptation

If adaptation to pattern A reduces sensitivity to A but does not affect sensitivity to B, then it may be assumed that the two patterns are processed by non-identical underlying structures.
Spatial Frequency Specific Adaptation

1. Measure a baseline CSF.

2. Adapt to a high-contrast grating of a single spatial frequency.

3. Measure CSF again.

4. In-between trials, may need to readapt (top-up adaptation).
Spatial Frequency Specific Adaptation

• If a single channel underlies the CSF, then adaptation should lead to a reduction in CS across all SFs.

• If the CSF represents the envelope of sensitivities of multiple channels tuned to different SFs, then adaptation to a single SF would produce a loss in CS over a restricted range of SFs.
Spatial Frequency Specific Adaptation

Blakemore & Campbell (1969)
Adapting to Square-wave Gratings

Blakemore & Campbell (1969)
Adapting Frequency: Low SFs

For adapting frequency below 3 c/deg, tuning functions were still centered upon 3 c/deg.

Does this mean there are no SF channels below 3 c/deg?

Blakemore & Campbell (1969)
No SF Adaptation Below 3 c/deg?

When a large display is used, the loss in CS remains centered on the adaptation frequency.

De Valois (1977)
Contrast Sensitivity Enhancement

- Frequencies near the adaptation frequency: a loss in CS.
- Frequencies very different from the adaptation frequency: an enhancement in CS.

De Valois (1977)
Spatial Frequency Specific Aftereffects

Adaptation to a single SF grating also leads to a change in the perceived appearance of certain grating patterns.
Blakemore-Sutton Effect
Blakemore & Sutton (1969)

• Gratings of a SF lower than the adaptation frequency appeared perceptually to be even lower after adaptation.

• Gratings of a SF higher than the adaptation frequency appeared perceptually to be even higher after adaptation.
Blakemore-Sutton Effect

Spatial Frequency Match

Spatial Frequency (c/deg)

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Blakemore & Sutton (1969)
Blakemore-Sutton Effect

Blakemore & Sutton (1969)
Basis of Adaptation

Channel sensitivities

Spatia frequency

Relative activity

Spatial frequency

Perceived

Test

Adapt

Retest
Orientation Specificity

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Blakemore & Nachmias (1971)
Klein, Stromeeyer & Ganz (1974)
Spatial Frequency
Selective Masking

• Masking: the detectability (visibility) of a stimulus (target) is affected by the presence of another stimulus (mask).

• If the presence of a mask has no effect on the detectability of the target, then can be assumed that mask and target are detected by independent mechanisms.
What Causes Masking?

- Both the mask and the target excite some of the same neurones.
- Or, the channels underlying the detection of the mask and the target can be different but are mutually inhibitory. Activity in one directly inhibits the other, thus effectively increasing the threshold of the second mechanism.
Property of SF Masking

Extends only over a limited SF range, implying the presence of multiple channels that are considerably more narrowly tuned than the overall CSF.
SF Masking

Test frequency = 2 c/deg

Legge & Foley (1980)
Grating-by-Grating Masking

- Masking of a single SF grating by another single SF grating.
- Peak masking occurs when the mask and the target are identical or very close in SF (and orientation) and the mask is of high contrast.
- Masking decreases as the difference in SFs between the mask and the target increases.
Subthreshold Summation

• A stimulus can only be detected if it produces responses that exceed the criterion of its detecting mechanism (channel).

• If stimuli A and B are both subthreshold, neither one will be detected, but their combination might be detected.

• Assumption: the system is linear.
Subthreshold Summation

- Does not require the two subthreshold stimuli to be of identical SF, as long as the channel shows linear summation within its passband.
- By measuring the frequency range over which subthreshold summation occurs, bandwidth of the channel can be derived.
Sachs, Nachmias & Robson (1971)

• Subthreshold summation is found between gratings of closely spaced SFs but not between more widely spaced ones.

• Results imply the existence of multiple channels, each of which is more narrowly tuned than the overall CSF.
Neurophysiological Evidence

De Valois, Albrecht & Thorell, 1982
• Neurons in the visual system exhibit a range of SF tuning.
• SF tuning becomes narrower from the retina to the visual cortex.
Bandwidth

De Valois, Albrecht & Thorell, 1982
SF Filtering and Vision

‘Low’ spatial frequency filters encode coarse luminance variations in the world (e.g. large objects, overall shape)

‘High’ spatial frequency filters respond to the fine spatial structure of the world (e.g. small objects, detail)
SF Filtering and Vision
SF Channel Selectivity

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Wilson’s SF Model