Texture mechanisms pool multiple first-order channels

Michael S. Landy & Zachary M. Westrick

New York University
Dept. of Psychology and
Center for Neural Science

Outline

- Introduction: 2nd-order CSFs are flat or nearly so, but shouldn't be
- Expt. 1: Cross-carrier adaptation indicates 1st-order pooling
- Expt. 2: Pooling is over multiple, nonlinear, 1st-order channels
- Conclusions

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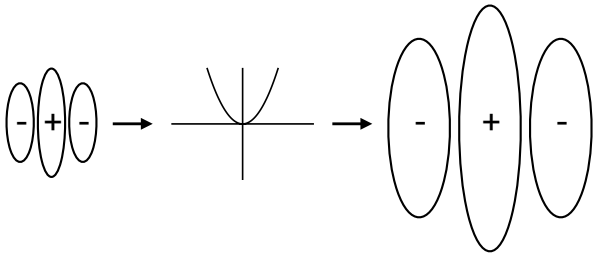
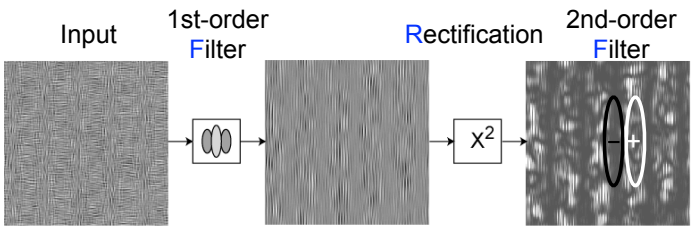
FRF Model

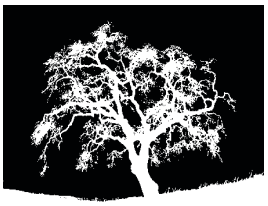


Filter Rectify Filter

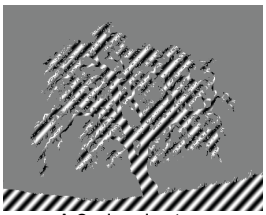
FRF Model



FRF with V1 filters is low-pass



A tree



A 2nd-order tree

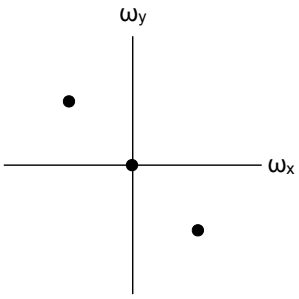
FRF output with V1 filter

FRF output with wide-band filter

Stimulus generation: one carrier

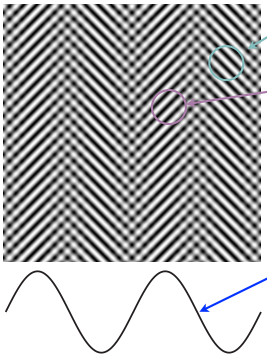
Space

Spatial frequency

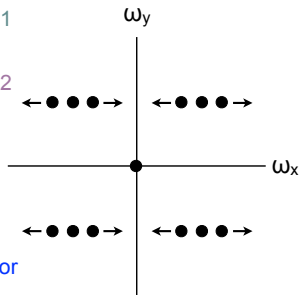


Stimulus generation: two modulated carriers

Space



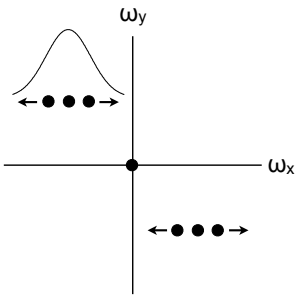
Spatial frequency



FRF model: F_1

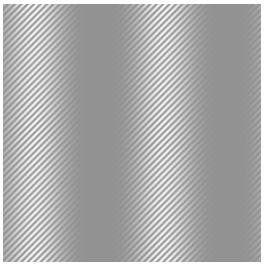
Space

Spatial frequency

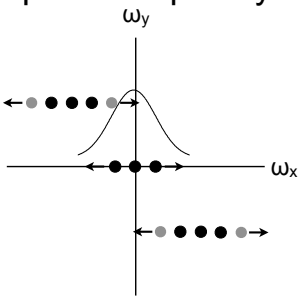


FRF model: R (squaring)

Space



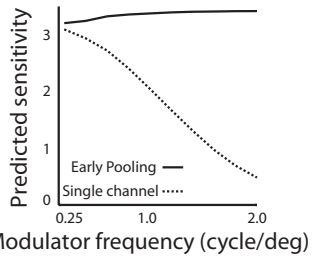
Spatial frequency



Therefore: 2nd-order (modulation) sensitivity should be low-pass!

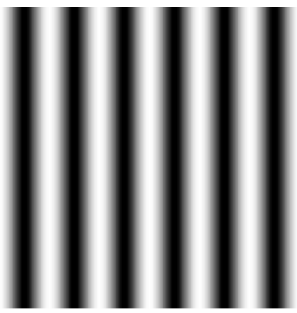
Westrick, Henry & Landy, *Vis Res*, 2013

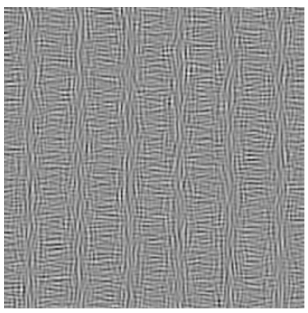
Simulations agree: pooling improves high-SF sensitivity



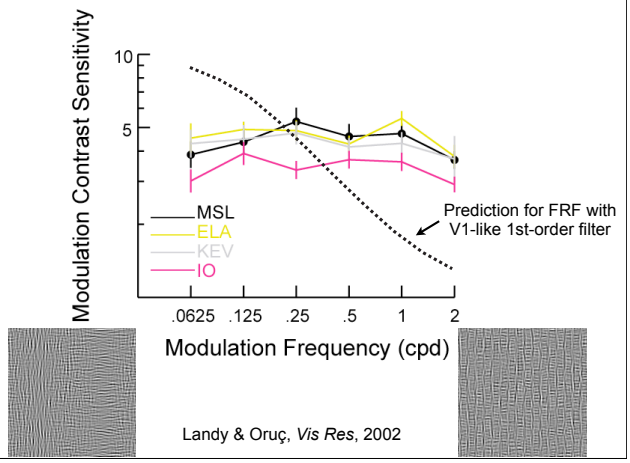
Early pooling (of linear filters) flattens the 2nd-order CSF.

Typical stimulus for measuring CSF: Sine wave grating



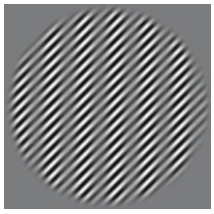


2nd-order contrast sensitivity

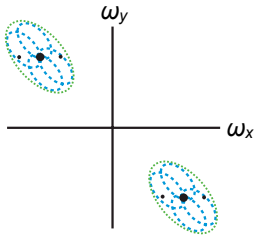


Landy & Oruç, *Vis Res*, 2002

Hypothesis: First-order channels are pooled in FRF



Contrast-modulated grating



Demodulate using pooled 1st-order filters

Outline

- Introduction: 2nd-order CSFs are flat or nearly so, but shouldn't be
- Expt. 1: Cross-carrier adaptation indicates 1st-order pooling
- Expt. 2: 2nd-order CSF is low-pass at low 1st-order contrast
- Conclusions

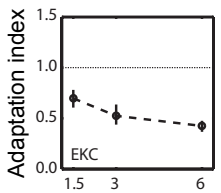
Task and stimuli

Adapter: high 1st-order SF

Test: vary 1st-order SF

Task: 2AFC detection of a 2nd-order grating (V or H). Determine 2nd-order contrast threshold.

Expt. 1: Sample results



Adaptation index =

$$\frac{T_0^{90} + T_{90}^{0}}{T_0^{0} + T_{90}^{90}}$$

Modulator orientation:

Adapter

Test

Adapter carrier frequency: 6 cycle/deg

Significant adaptation with test carrier 2 octaves lower than adapter carrier!

Expt. 1: Summary

- We found significant 2nd-order adaptation effects for test stimuli with carrier frequencies distant from the adapter's carrier frequency.
- This is consistent with adaptation taking place at the 2nd-order filter stage (or later) for a mechanism that pools multiple 1st-order filters (or somehow constructs a wide-band 1st-order filter).

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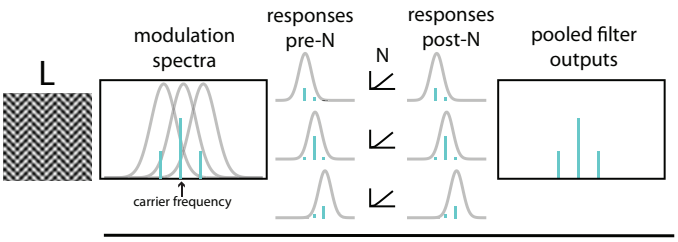
Expt. 2: Rationale

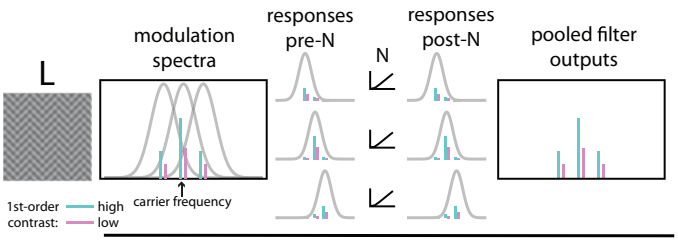
What "1st-order" mechanisms are pooled? How can we show that multiple 1st-order mechanisms are pooled rather than just using or constructing one wide-band linear filter?

If typical 1st-order spatial frequency channels (simple cells, i.e., FR) are pooled, then lowering 1st-order contrast should reduce sensitivity more for high 2nd-order SF stimuli than for low SF stimuli.

Expt. 2: Rationale



Expt. 2: Rationale



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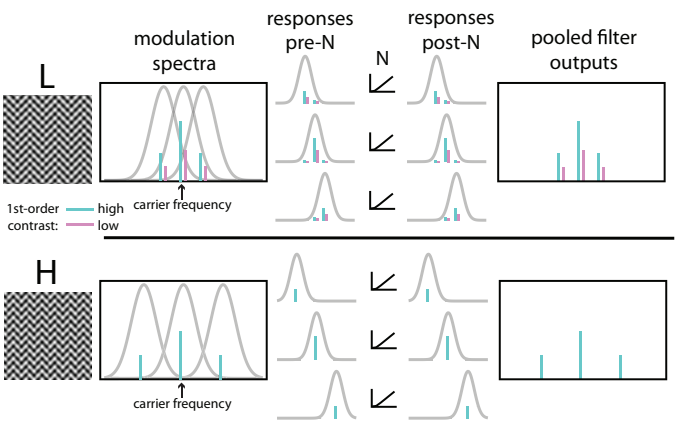
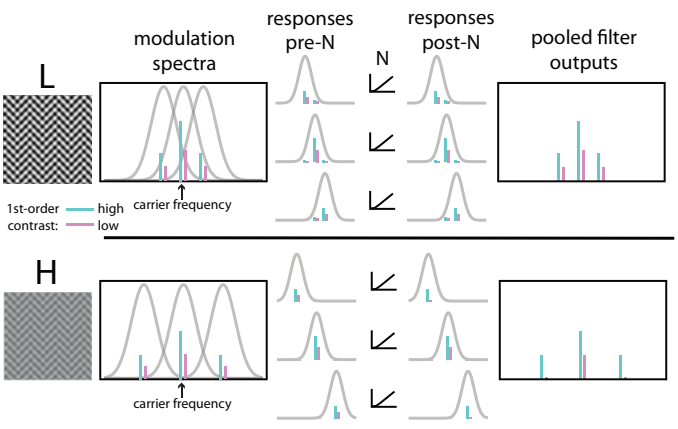


Expt. 2: Rationale



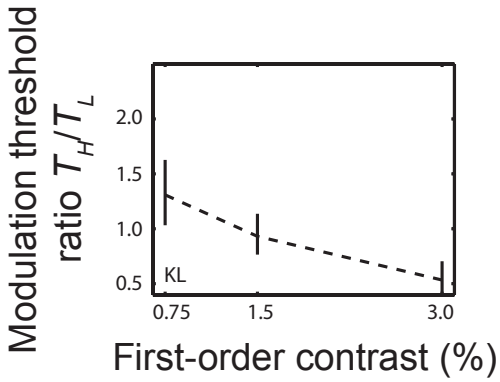
Expt. 2: Methods

Carrier:
4 cycle/deg
0.75%, 1.5% and 3% 1st-order contrasts

Modulator: 0.5 and 1.5 cycle/deg

Task: Discriminate 2nd-order grating orientation (V vs. H). Determine 2nd-order contrast threshold.

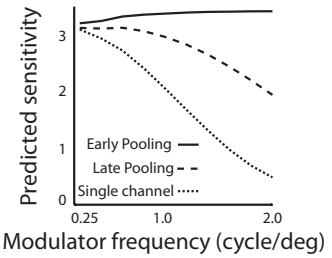
Expt. 2: Sample results



Expt. 2: Summary

- As 1st-order contrast is reduced to near-detection-threshold levels, 2nd-order contrast thresholds are increased more for high- than for low-frequency 2nd-order gratings
- This is consistent with a 2nd-order mechanism that pools over 1st-order mechanisms that include an accelerating nonlinearity.

Simulations suggest pooling improves high-SF sensitivity



Late pooling (of nonlinear 1st-order mechanisms) also flattens the 2nd-order CSF.

Conclusion

- 2nd-order contrast sensitivity for orientation-modulated stimuli is nearly flat over a wide range of SFs.
- In two experiments, we show that this results from 2nd-order mechanisms that pool over nonlinear 1st-order mechanisms with a wide range of preferred SFs.