The orientation filter we use to identify objects: object recognition by a donut

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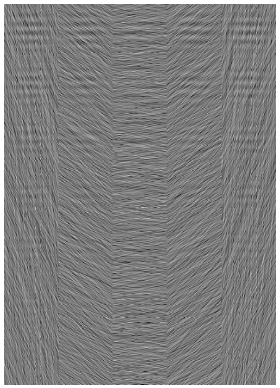
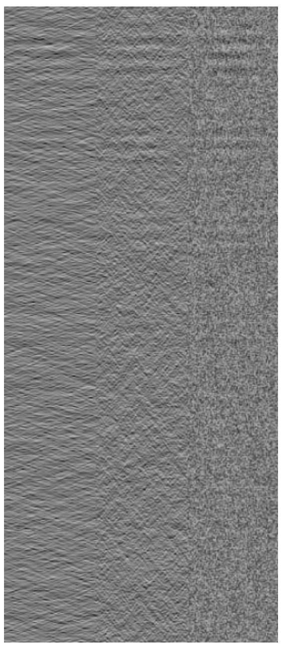
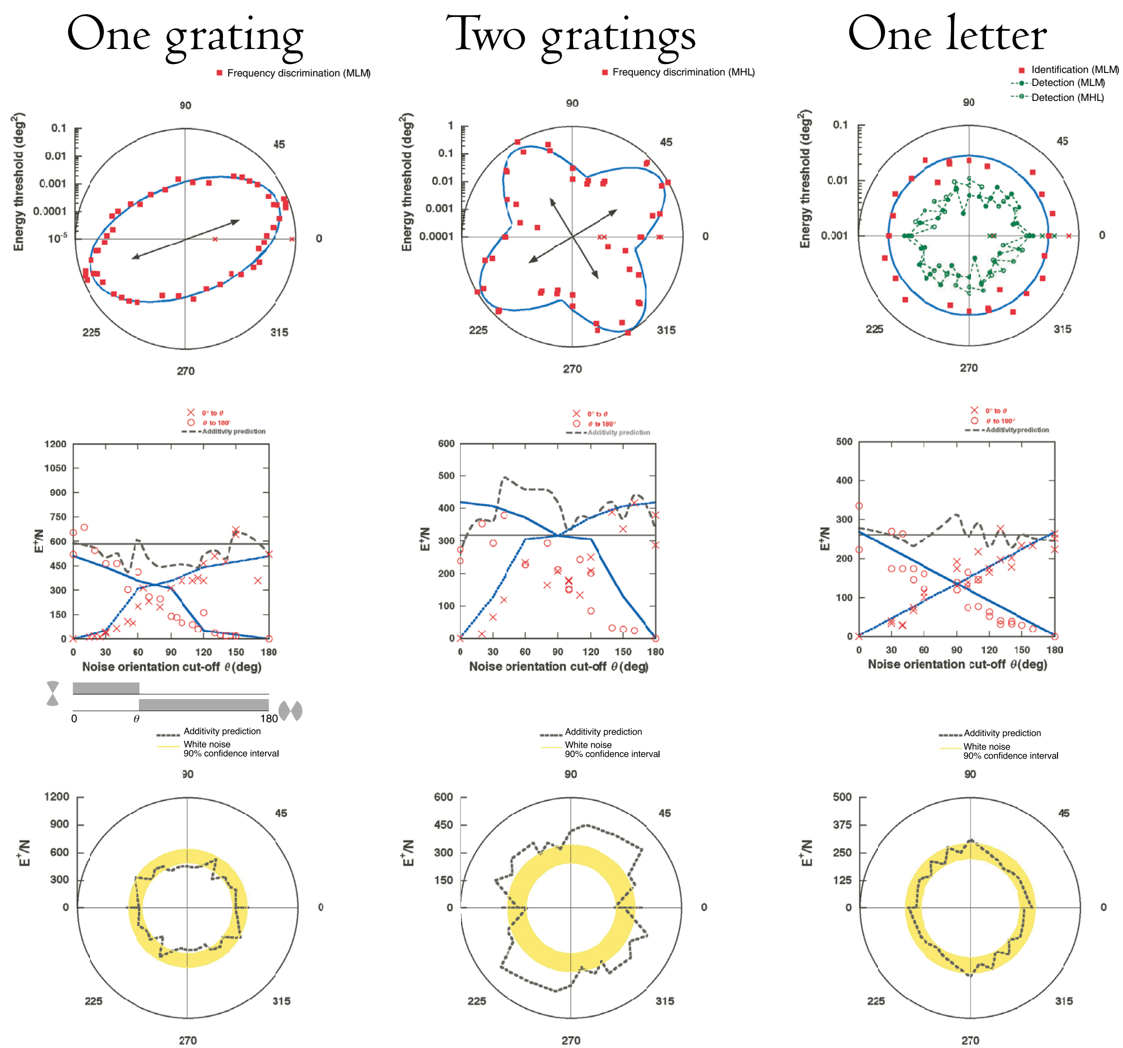
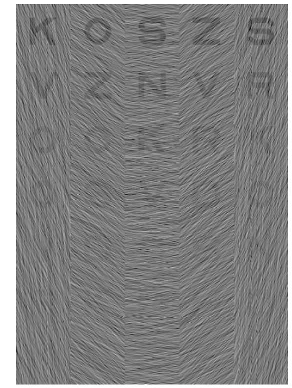
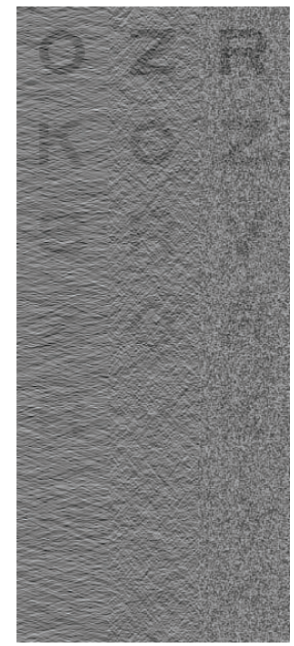
Olzak and Thomas posited "cigar" channels, which integrate across a wide range of frequency and a narrow range of orientation, and "donut" channels, which integrate across all orientations and a narrow range of frequency. Majaj et al. (2002) used critical band masking to measure the radial frequency tuning of the channel that observers use to identify letters, and always found the same one-or-so-octave bandwidth: no cigar. We did similar critical band masking experiments, but restricting orientation, instead of radial frequency, of the noise spectrum. With a grating signal, we reveal a channel tuned to the grating orientation, as expected. With a letter signal, we reveal a channel that is equally sensitive to all orientations: a donut. It is a first-, not second-, order channel, as shown by the fact that the threshold energy elevation sums linearly across orientations. Thus, the letter identification channel is a donut.











Caption for figures

COLUMNS. Three kinds of stimuli, with appropriate tasks. Column 1 - one grating: is its frequency f or $2f$? Column 2 - two orthogonal gratings superimposed: do they have the same frequency? Each can be f or $2f$. Column 3 - a letter: either 1 of 8 identification or two-interval-forced-choice detection.

ROW 1 shows the elevation of threshold energy produced by a narrow orientation band (15 or 30 deg), as a function of the orientation of that band. One grating yields an ellipse, a traditional orientation-selective channel. Two gratings, since the task requires the observer to see *both* gratings, reveals two channels. Finally, a letter yields a circle, with no orientation tuning at all; threshold elevation is independent of orientation. But is it a channel? Read on.

ROW 2. If the tuning displayed in Row 1 represents the orientation-dependent gain of a single filter, then based on much other work, we expect effects of noise to be additive. The elevation of threshold energy by the sum of two noises should equal the sum of the elevations of the noises applied one at a time. We measured threshold for two complementary bands of noise, 0° to θ (plotted as X's) and θ to 180° (plotted as O's). These two noises sum to be white noise, 0° to 180°, and that threshold is plotted as a horizontal black line (—). The sum of the two elevations is plotted as a dashed line (---). The prediction succeeds, noise is additive, for one grating and one letter. As expected, noise is *not* additive for two orthogonal gratings. The blue lines (—) show another noise additivity test, with the same conclusion, which sums the narrow-orientation thresholds in Row 1 to predict the wideband thresholds here in Row 2.

ROW 3. A polar plot of the same data. For one grating and one letter, the results are within the yellow 90% confidence interval of the prediction. This shows that there is one channel that is linearly integrating noise power across all frequencies, weighted by the filter in Row 1. For two gratings, the prediction fails, as expected, confirming that the observer uses more than one channel to see two orthogonal gratings.

Pelli, D.G., Lee, M.H., Martelli, M., Majaj, N., Object recognition by a donut, Vision Sciences Society, Sarasota, Florida, May 10-15, 2002.
http://psych.nyu.edu/pelli/