

Lines and spots are efficiently detected

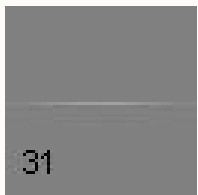
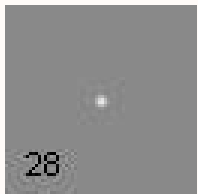
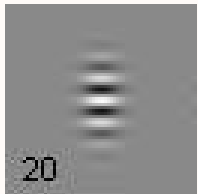
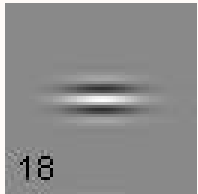
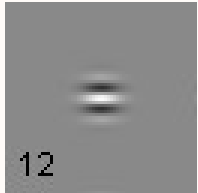
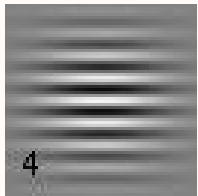
Albert Ahumada

Andrew Watson

NASA Ames Research Center

Lauren Scharff

Stephen F. Austin State University

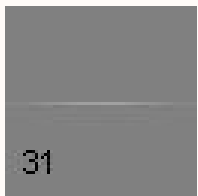
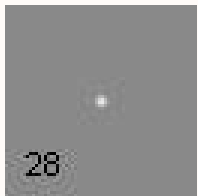
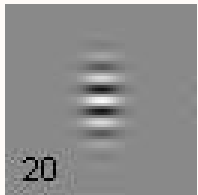
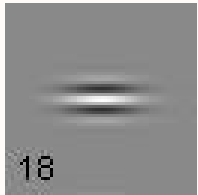
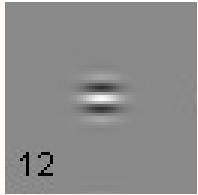
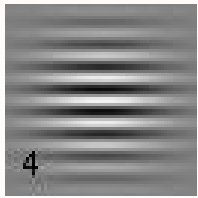


“What does the eye see best?”

is the title of the 1983 Nature article by Watson, Barlow, & Robson.

“**Best**” meant detected most efficiently **relative to** the ideal observer limited only by **quantum noise**.

They showed that the **best pattern** is then the one with the **lowest contrast energy threshold**.



Contrast Energy

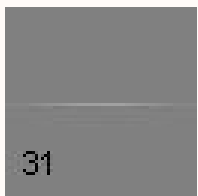
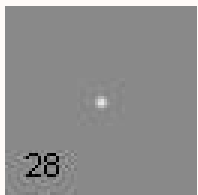
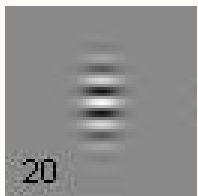
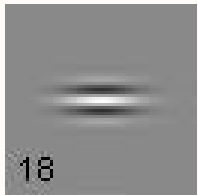
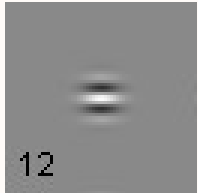
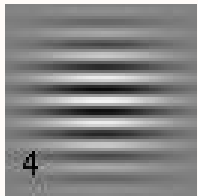
The contrast energy of a space-time contrast signal $c(x, y, t)$ is

$$E = dx dy dt \sum c(x, y, t)^2$$

dx is the pixel width,
 dy is the pixel height,
 dt is the pixel duration.

$$dBB = 10 \log_{10}(E/E_0)$$

$$E_0 = 10^{-6} \text{ deg}^2 \text{ sec}$$

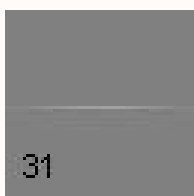
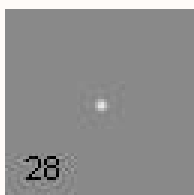
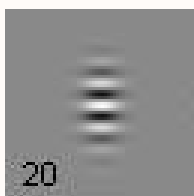
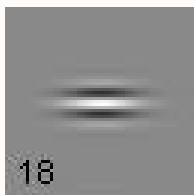
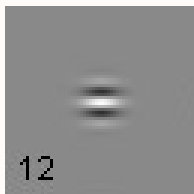
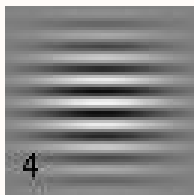
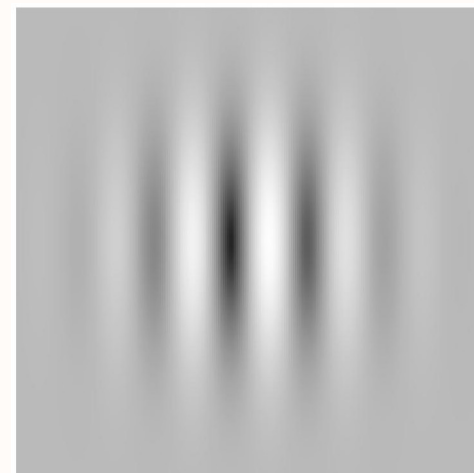


Watson, Barlow, & Robson

measured contrast energy thresholds for Gabors and squares. The best stimulus was a Gabor whose contrast over space (x, y) and time (t) was

$$\sin[2\pi(f_x x + f_T t)] \times \exp[-0.5((x/\sigma_x)^2 + (y/\sigma_y)^2 + (t/\sigma_T)^2)]$$

with $f_x = 7$ cycles/deg
 $\sigma_x = \sigma_y = 1/7$ deg
 $f_T = 4$ cycles/sec
 $\sigma_T = 1/16$ sec

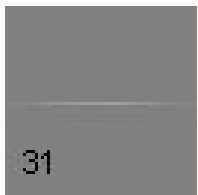
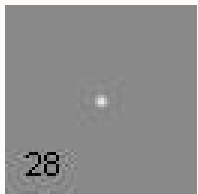
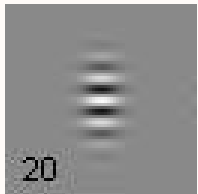
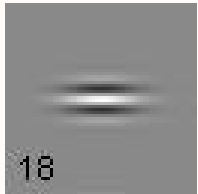
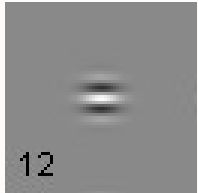
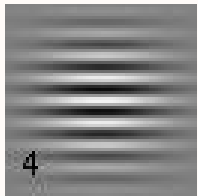
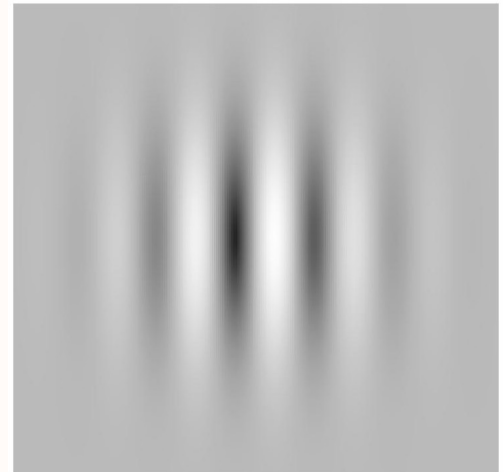


Watson, Barlow, & Robson

speculated that the **best stimulus** had the shape of the **detecting template**.

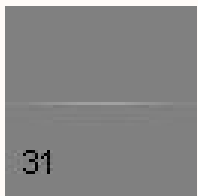
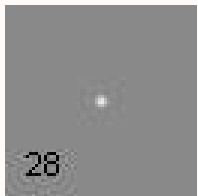
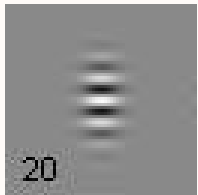
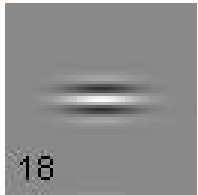
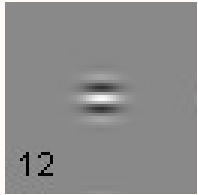
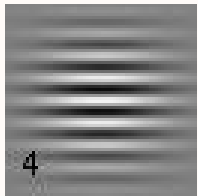
“... the detector spatial weighting function deduced here resembles the receptive field profiles of many **cortical neurones**. ...

Thus patterns like that ...
may be among
the elementary features
of visual perception.”

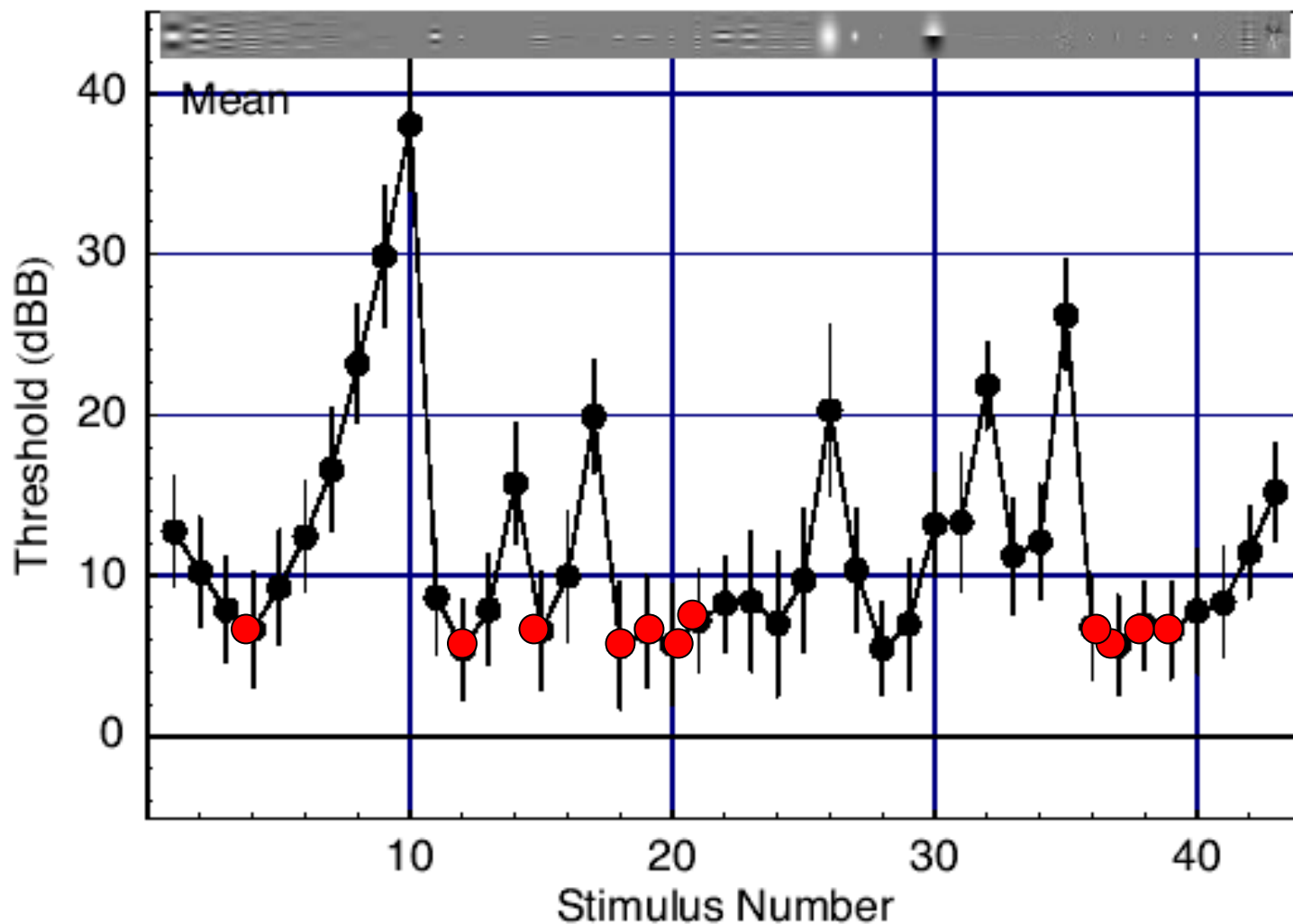


Modelfest

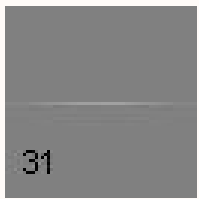
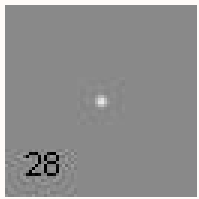
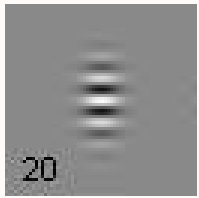
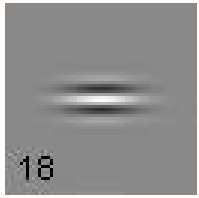
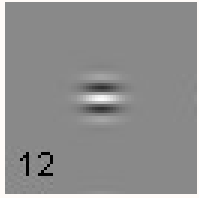
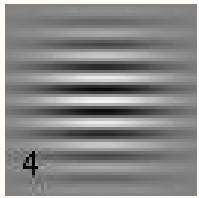
- Modelfest foveal pattern detection study began in 1996
- 16 observers from multiple labs
- 43 stimulus patterns (23 simple Gabors).



Modelfest Contrast Energy Thresholds

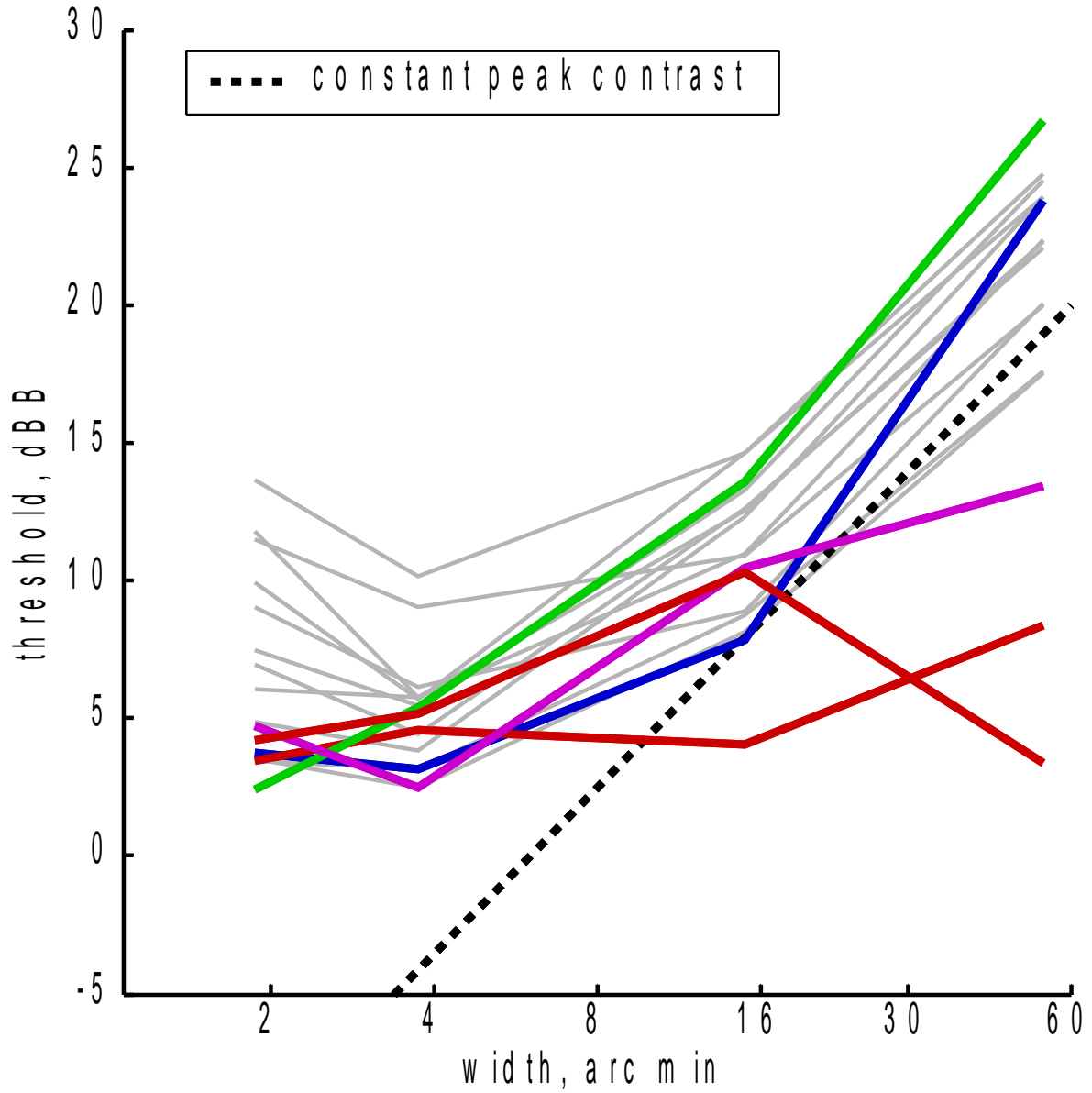


Watson (2000) 9 observers, ● 4 cpd Gabors

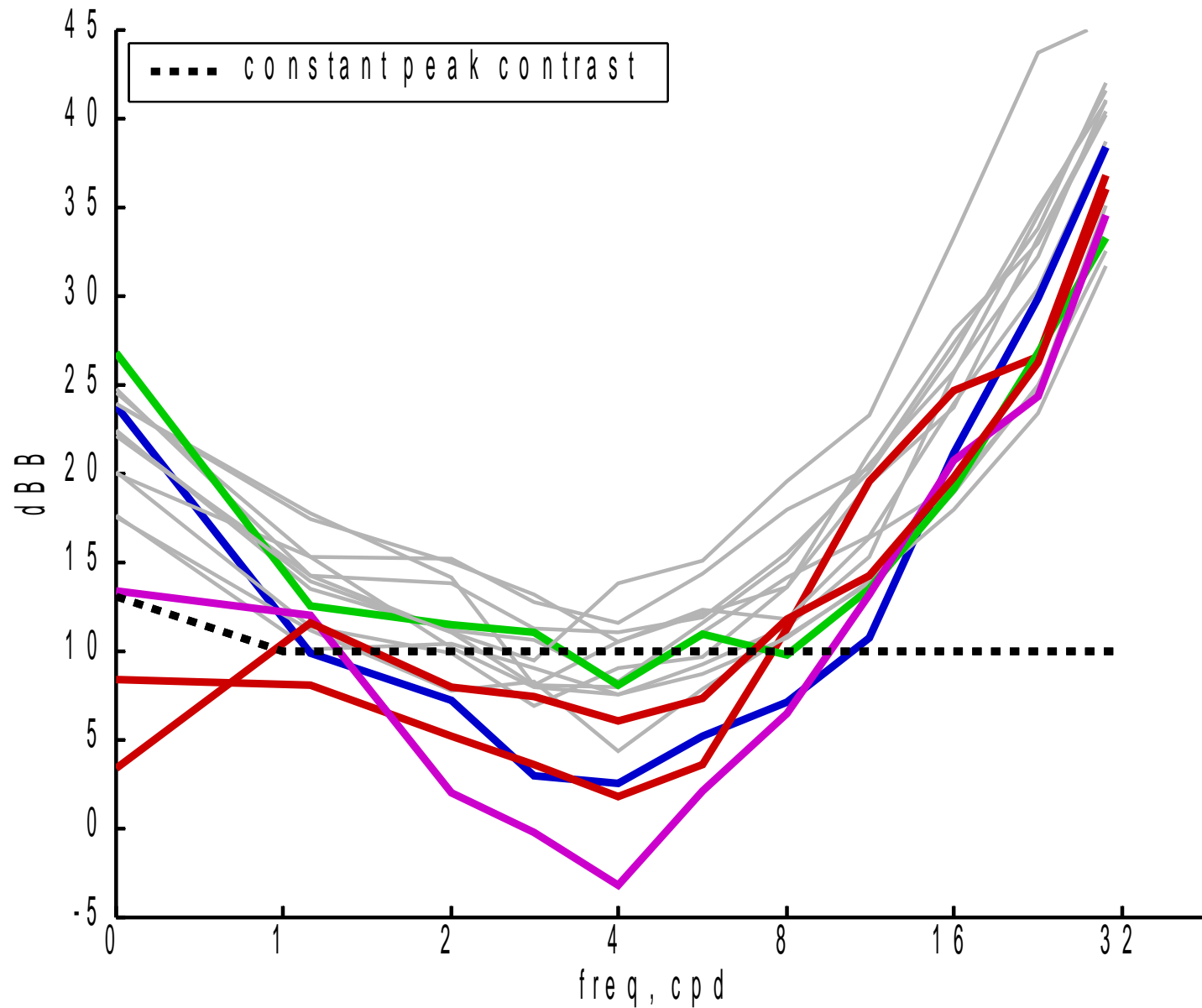


2007 VSS

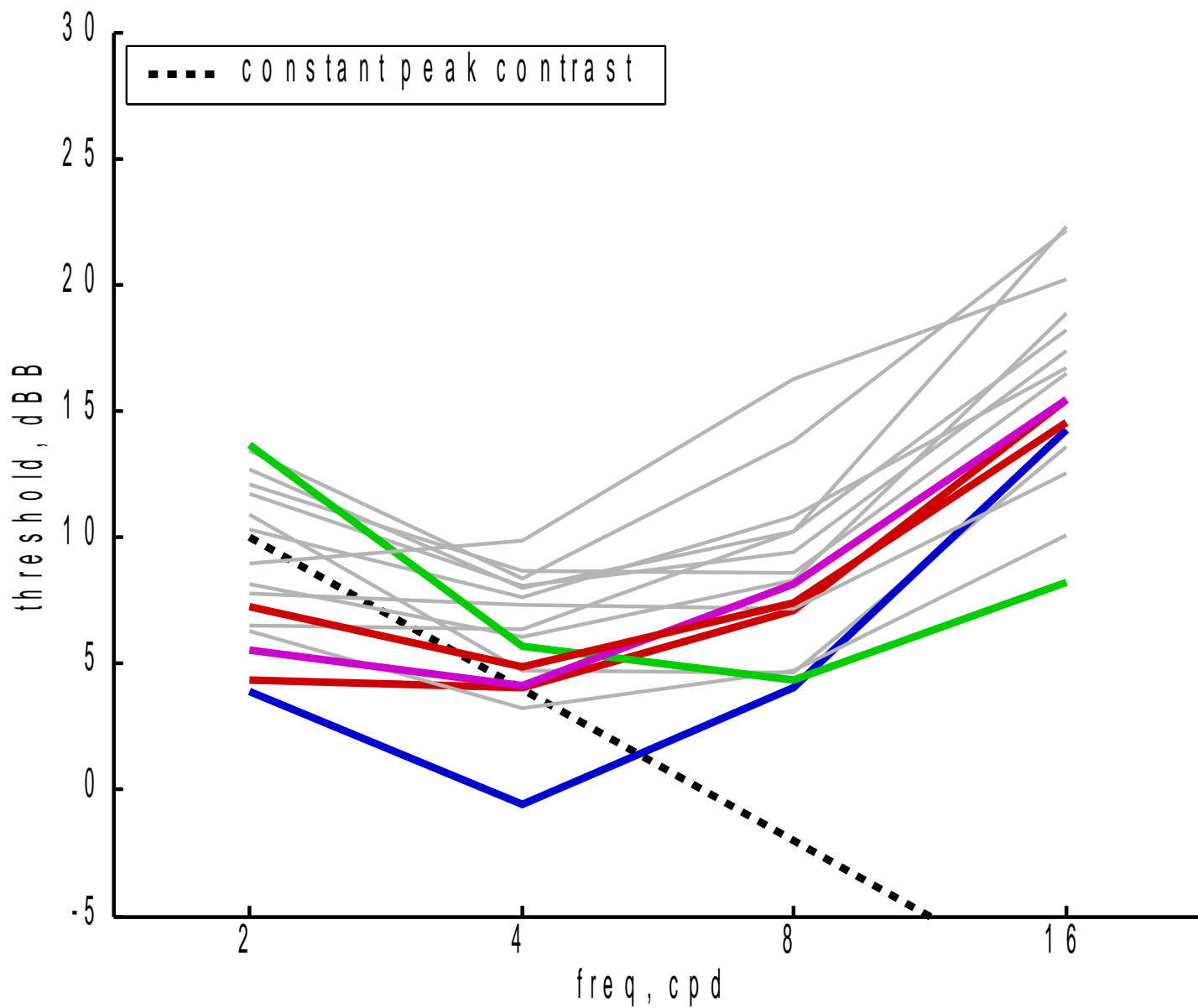
Model-fest Gaussian Spot Thresholds



Model of Fixed Width Gabor Thresholds



Modelfest 1 Octave Gabor Thresholds:



4

12

18

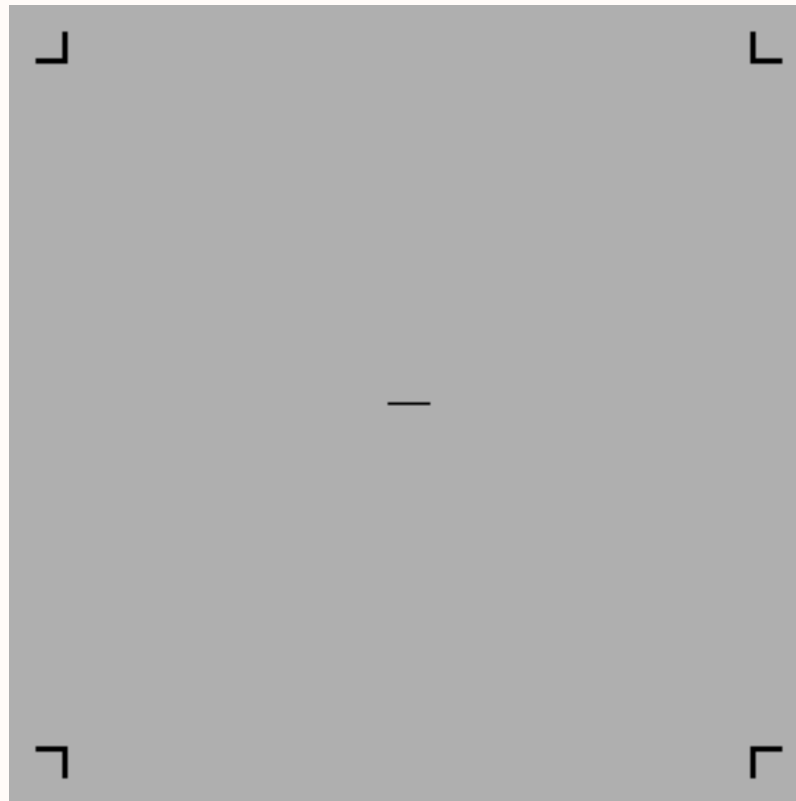
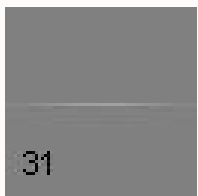
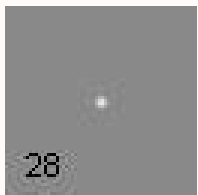
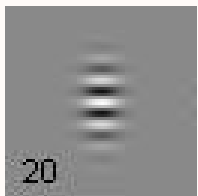
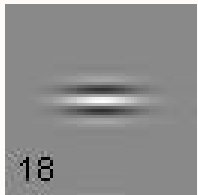
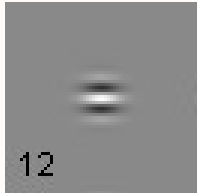
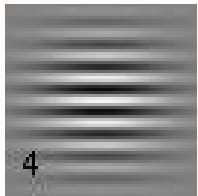
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28

31

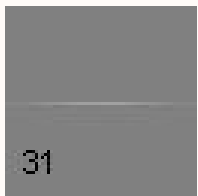
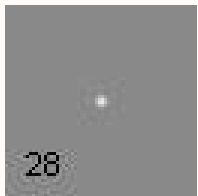
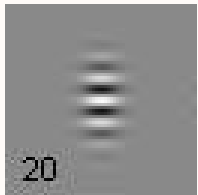
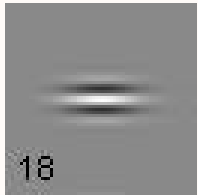
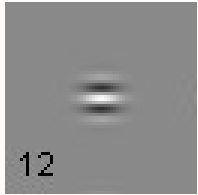
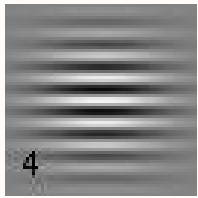
Example Stimulus Pattern

8 min x 0.5 min line



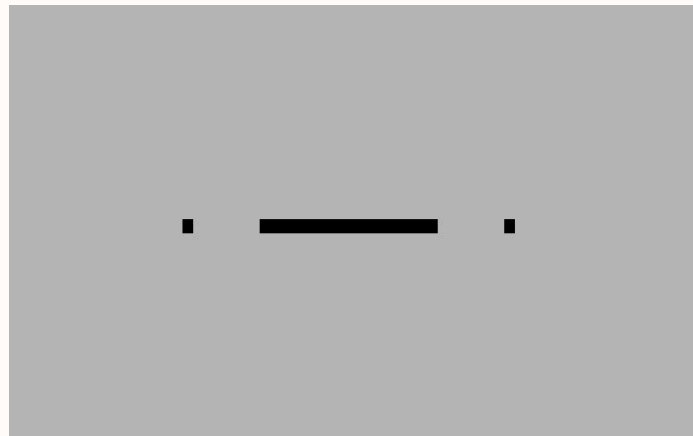
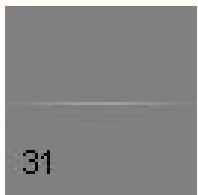
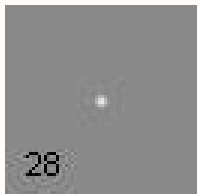
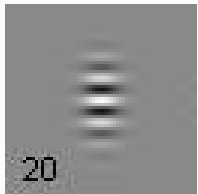
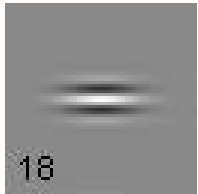
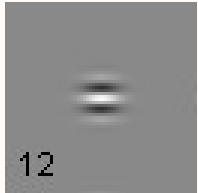
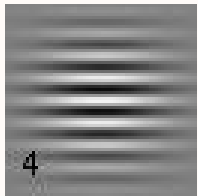
← 2.13 deg →

Ted Cohn: Mr. Uncertainty



Line Stimuli

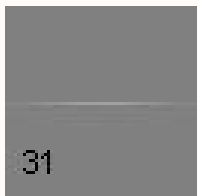
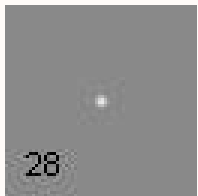
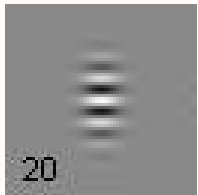
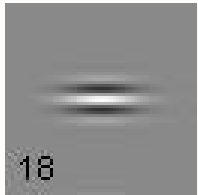
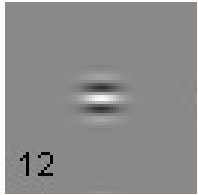
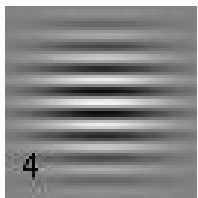
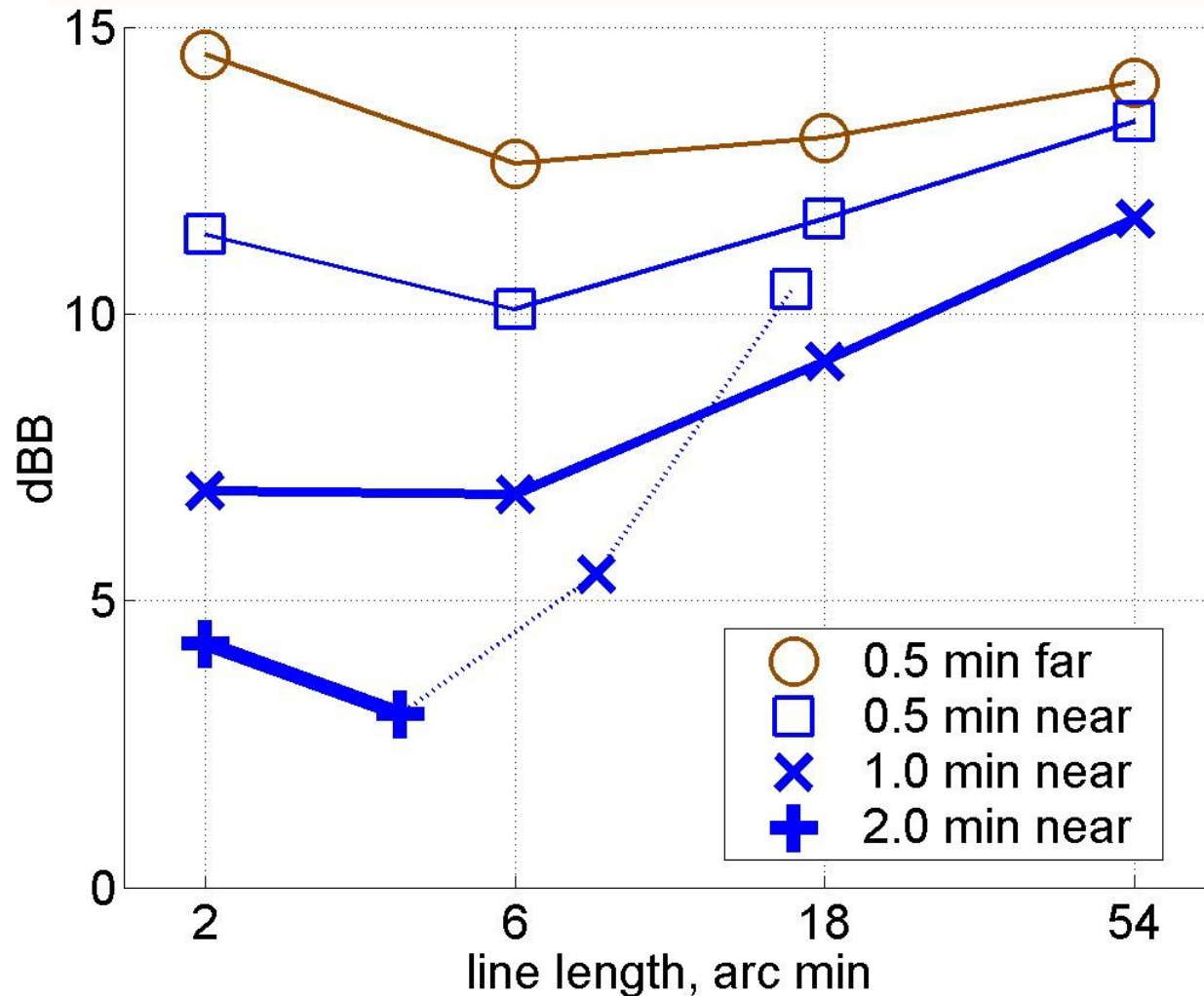
Near fixation markers condition



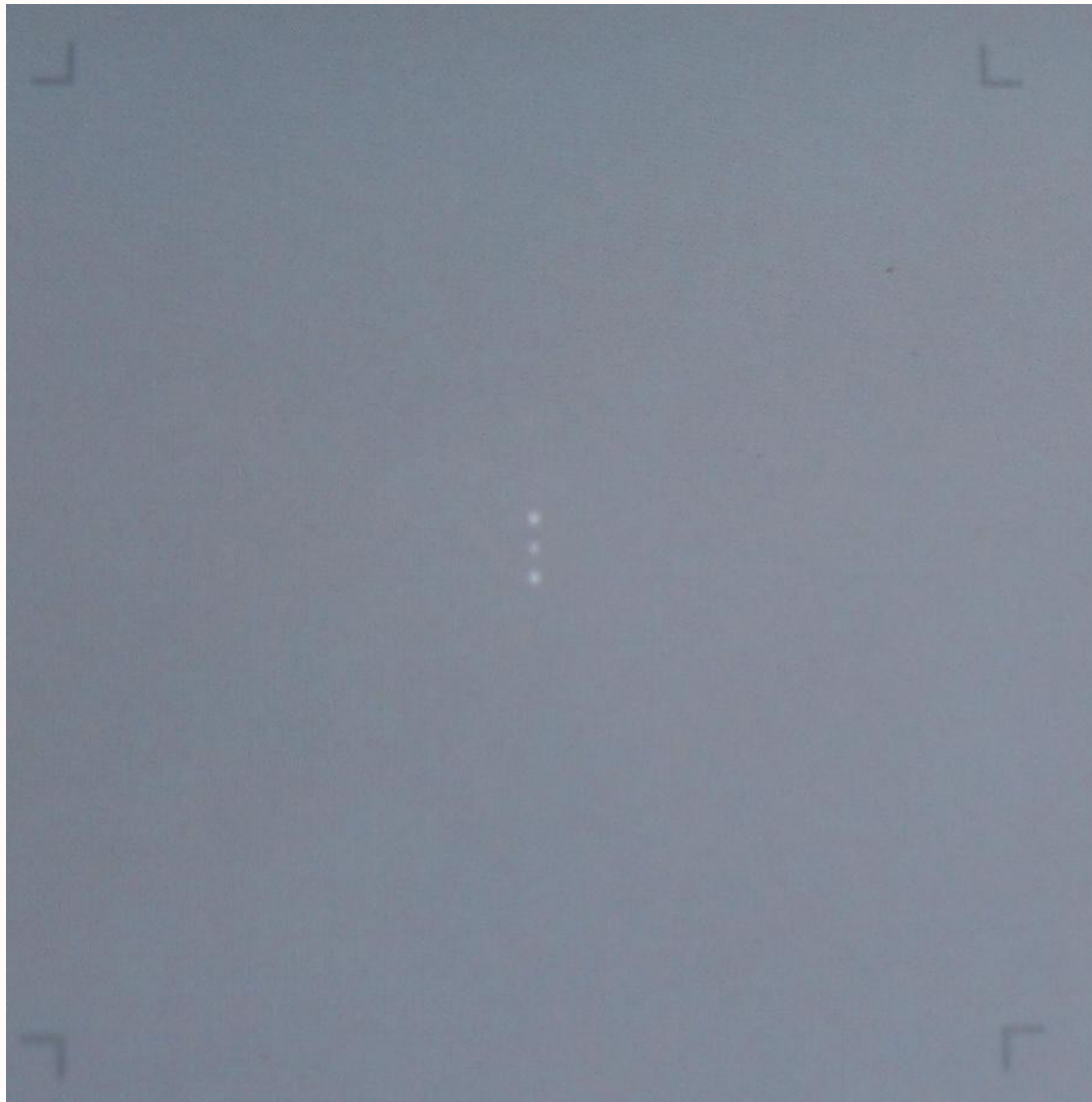
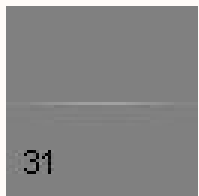
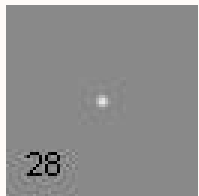
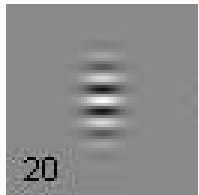
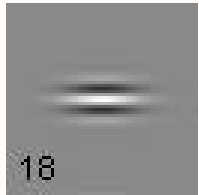
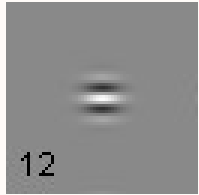
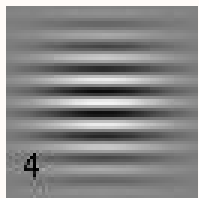
8 min x 0.5 min line

Line Width, Near and Far Markers

Contrast Energy Thresholds, CDM

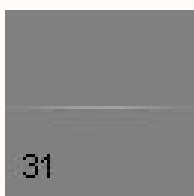
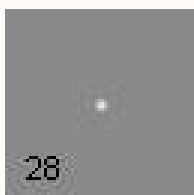
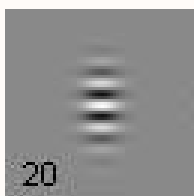
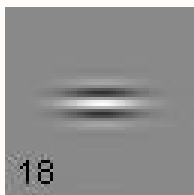
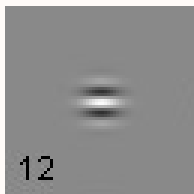
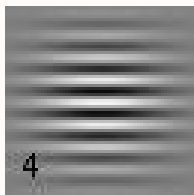
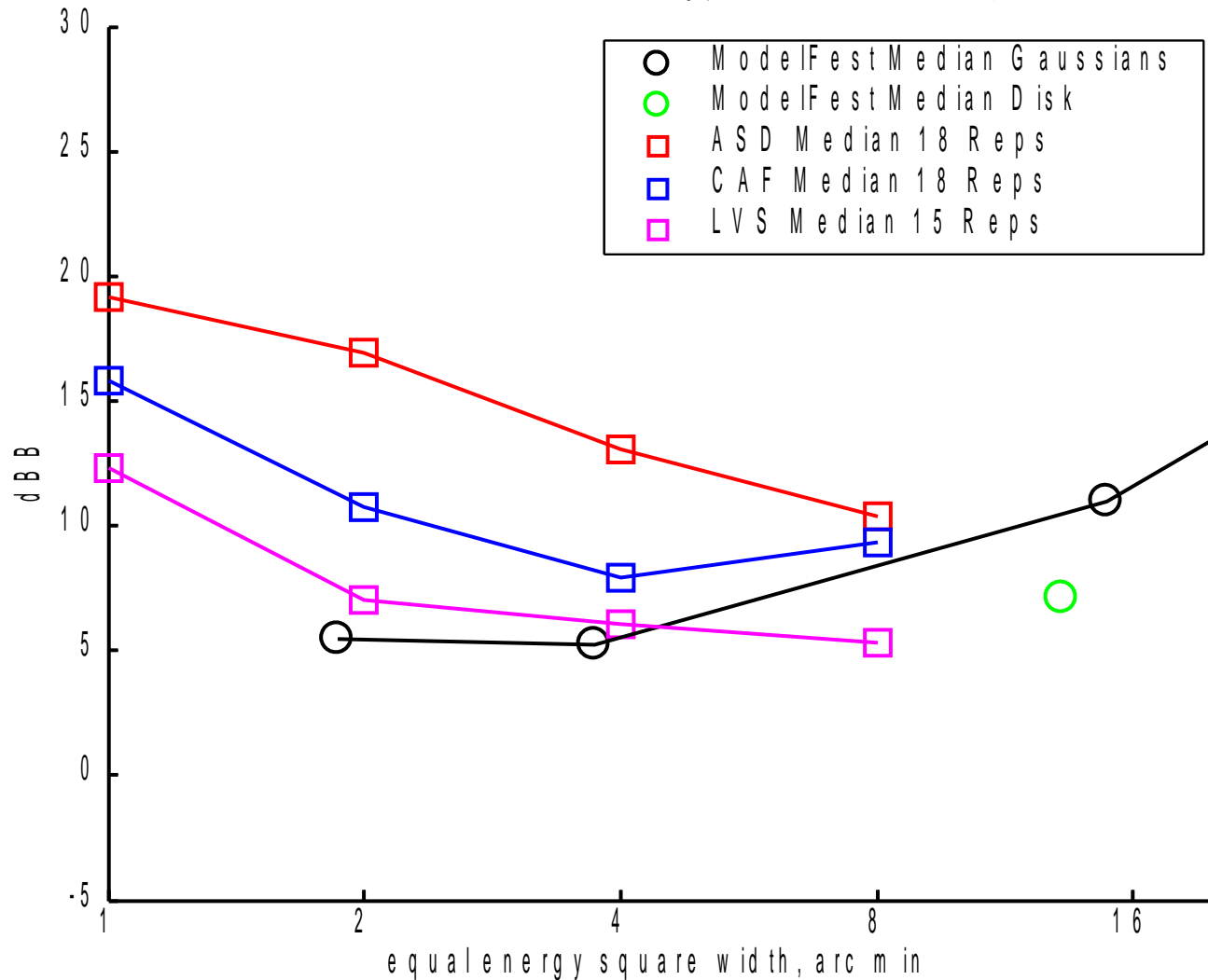


Example spot image

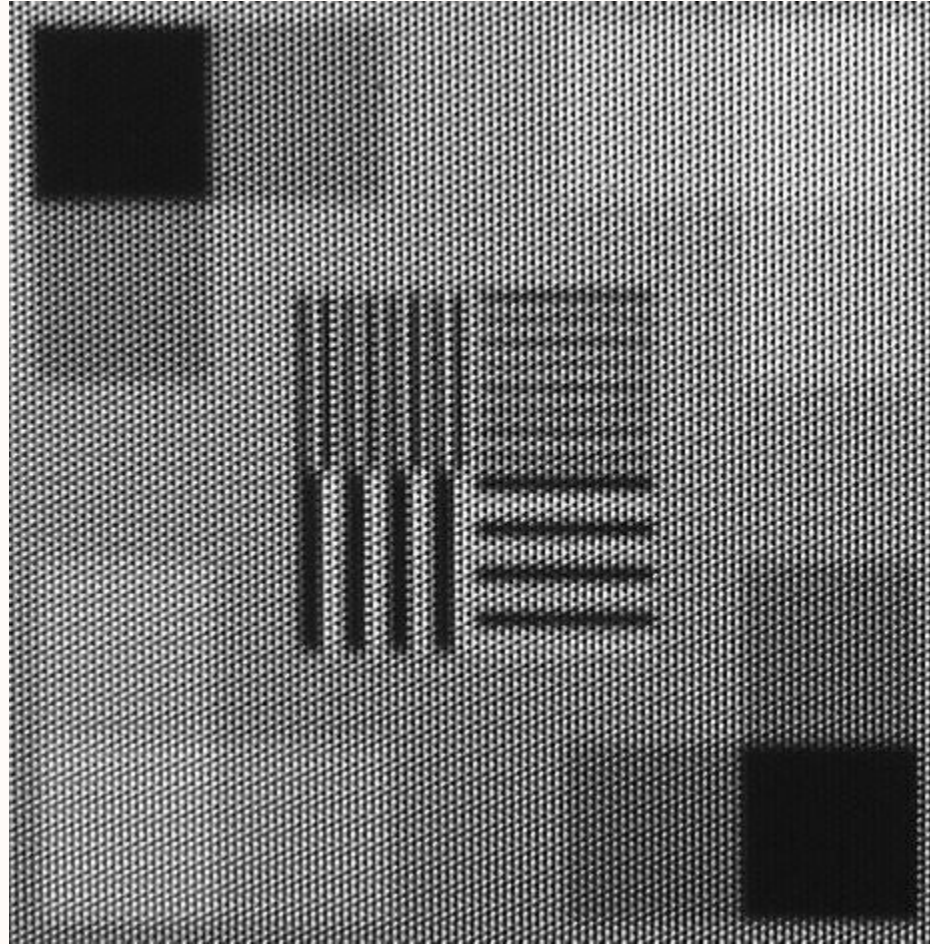
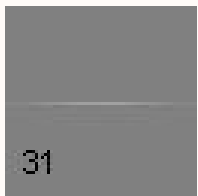
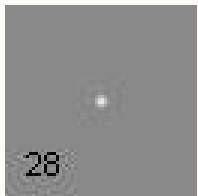
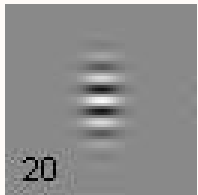
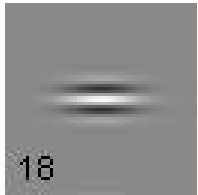
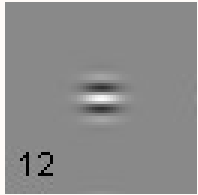
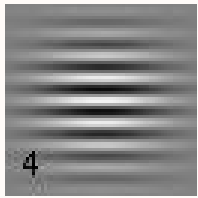


Spot Thresholds (Raw)

Uncorrected Contrast Energy Thresholds: Squares

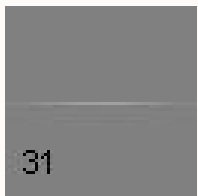
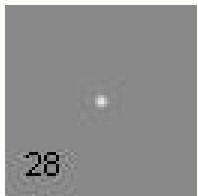
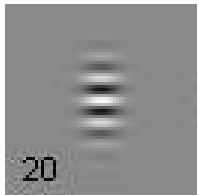
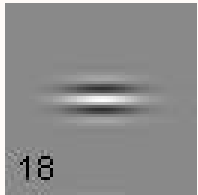
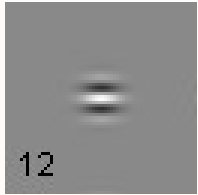
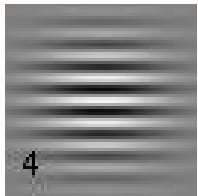
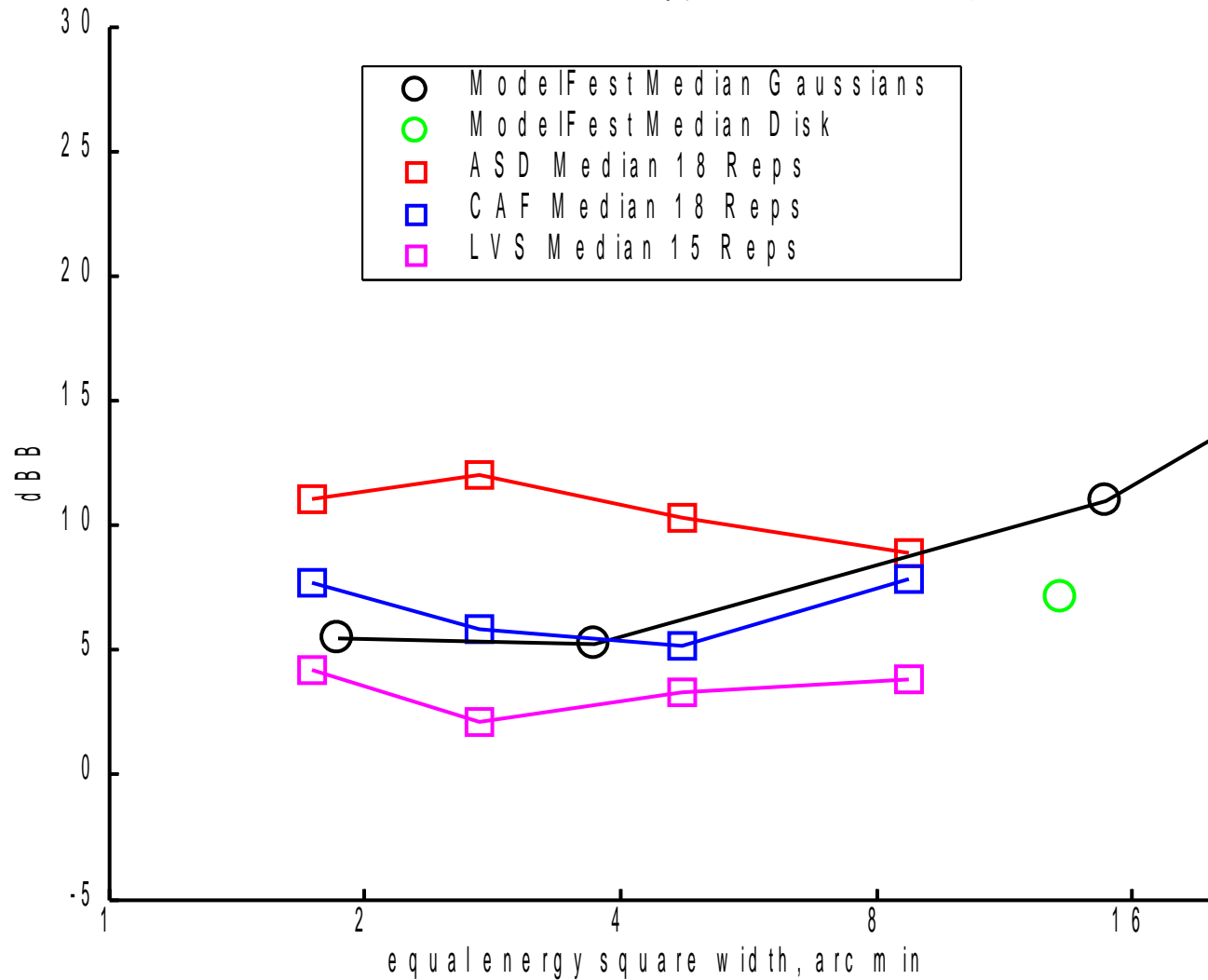


Calibration Image



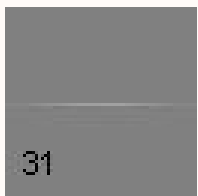
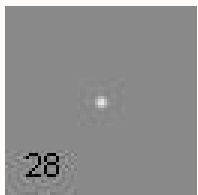
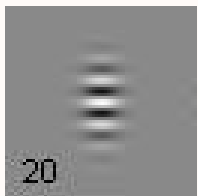
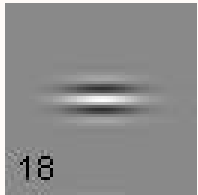
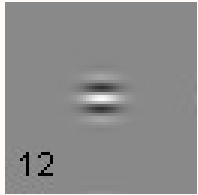
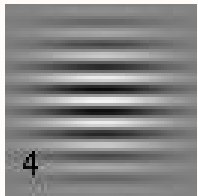
Spot Thresholds

Corrected Contrast Energy Thresholds: Squares



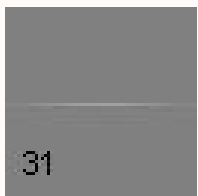
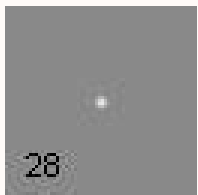
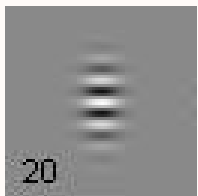
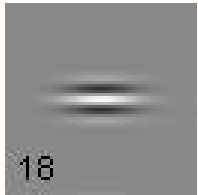
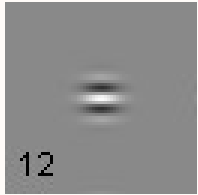
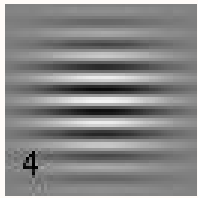
Conclusions: Modelfest

- Data show contamination from attempts to extend dynamic range (possibly minimal in median data).
- High frequency responses must have been affected by monitors.
- Would have also liked trial-by-trial data and more info on observers.



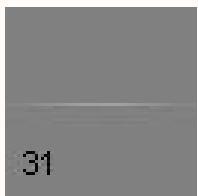
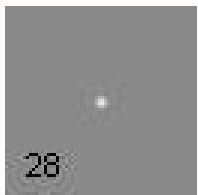
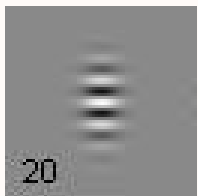
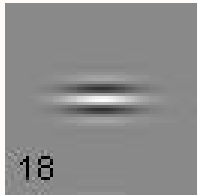
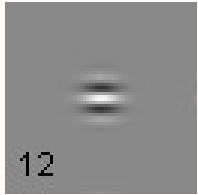
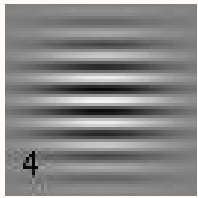
Incidental Surprises

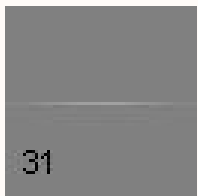
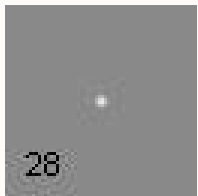
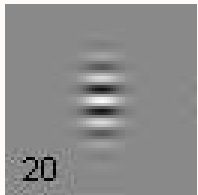
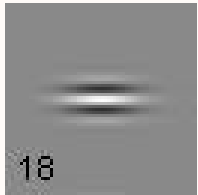
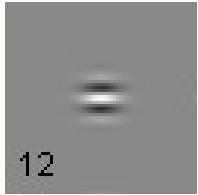
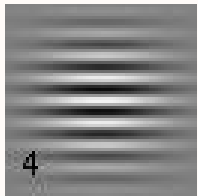
- Contrast energy is not a sensible measure for wideband stimuli without a filter.
- Some Macs have an inverse gamma (0.66) inserted after the Digital-to-Analog converters.



Conclusions: Our data

- **Spots** and **lines** can be just as visible as multi-cycle **Gabors** of the same contrast energy.
- Small pattern thresholds are affected by **position uncertainty**.
- Which visual images are best detected may **not** be a sensitive indicator of underlying mechanisms.





Thanks for
your
attention!