A spatial standard observer based on contrast energy

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Why a standard for contrast?

People want to be able to answer the question:

signal
or
"Is this target visible?"
or
display artifact

Successes

Luminance:

Off the shelf meter

On the light bulb carton

Sound pressure:

Off the shelf meter

Decibel scale: zero, units

Frequency weightings: dB Linear, dBA, dBC

Time constants: fast, slow, peak

Exponents: rectified, root mean square

Estimating a detection threshold

1) Find studies with similar targets and
   interpolate or extrapolate.

2) Use a computer model.
   a) Make image(s)
   b) Feed into computer model.
      (Now easier thanks to Michael Landy.)

3) Contrast energy approach.
   a) Compute stimulus contrast energy in dBB
   b) Correct for spatial frequency (and other variables)
      to get dBV (visible contrast energy)

Contrast energy in dBB

$$dBB = 10 \log_{10}(CE/10^{-6}) \text{ deg}^2 \text{ sec} = 10 \log_{10} CE + 60.$$

$$CE = \int\int\int C(x,y,t)^2 \, dx \, dy \, dt$$

$$CE = \text{frame duration} \times \text{pixel width} \times \text{pixel height} \times \sum_{\text{pixels}} \sum_{\text{frames}} C(\text{pixel, frame})^2$$

$$dBB = 60 + 10 \log_{10} C_{RMS} + 10 \log_{10} A_{EER} + 10 \log_{10} T_{EER}$$

C_{RMS} = Root Mean Square Contrast
A_{EER} = Energy Equivalent Rectangular Area
T_{EER} = Energy Equivalent Rectangular Duration

Table of Corrections

Contrast

constant, C:	$10 \log_{10} C + 0$
sine wave, peak = C:	$10 \log_{10} C - 3.0$
noise, stand. dev. = σ :	$10 \log_{10} \sigma + 0$

Area

ellipse, major and minor diameters, D, d:	
	$10 \log_{10} (D\ d) - 1.05$
Gaussian, SDs = $\sigma_X\ \sigma_Y$:	$10 \log_{10} (\sigma_X\ \sigma_Y) + 5.0$

Time

Gaussian, SD = σ_T :	$10 \log_{10} \sigma_T + 2.5$
half Gaussian, SD = σ_T :	$10 \log_{10} \sigma_T - 0.5$
raised cosine, duration = T:	$10 \log_{10} T - 4.3$
linear ramp, duration T :	$10 \log_{10} T - 4.8$

Observer Correction

"People are rarely as good as Horace Barlow" effect

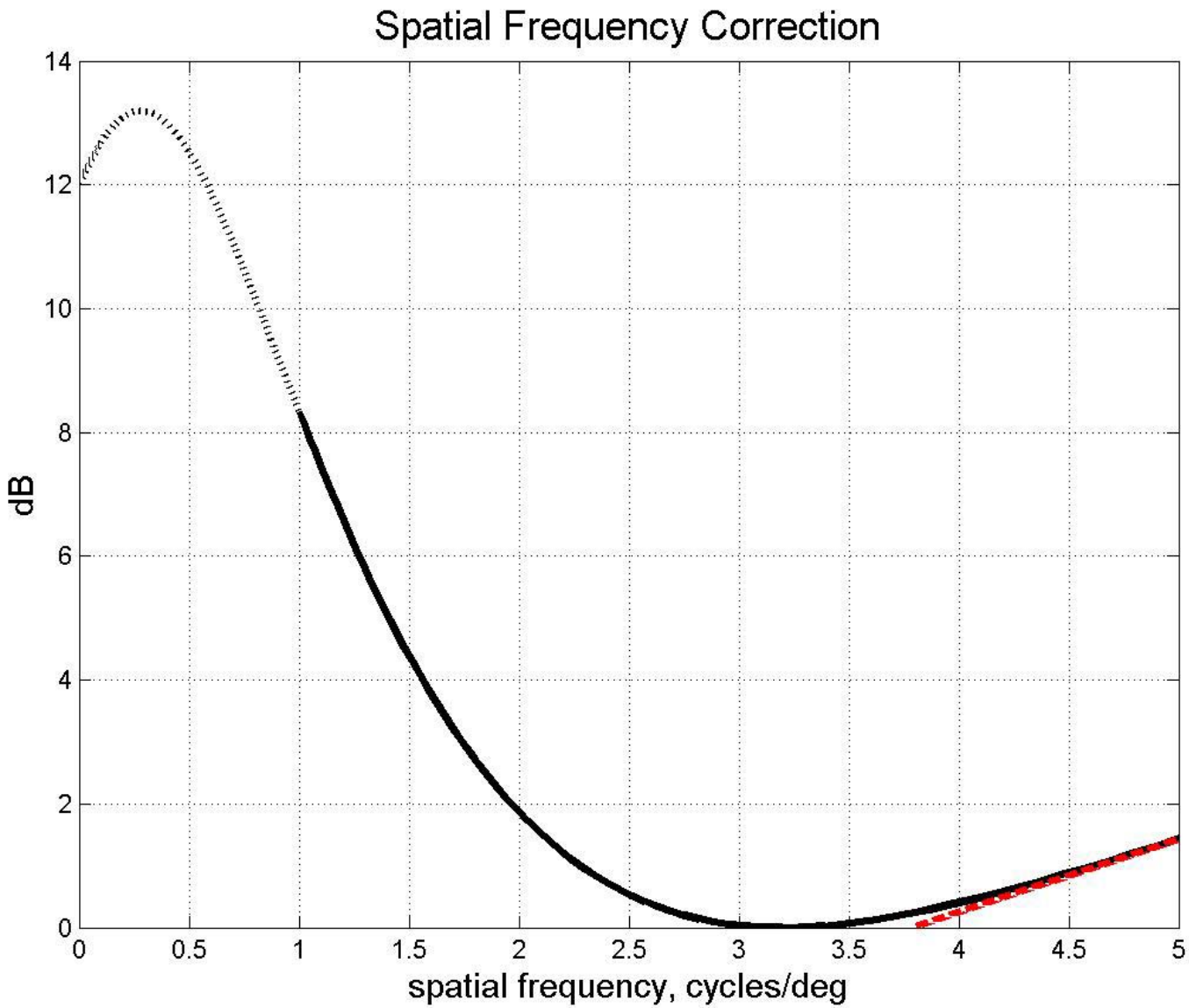
7 ± 2 dB

Spatial Frequency Correction

$$-20 \log_{10} \frac{CSF(f)}{\max(CSF(f))}$$

$$CSF(f) = e^{-f/c} - k\, e^{-(f/s)^2}$$

$$c = 7.4 \text{ cycles/deg}$$
$$s = 1.9 \text{ cycles/deg}$$
$$k = 0.85$$



For f > 5 cycles/deg, correction = 1.175 f - 4.45 dB

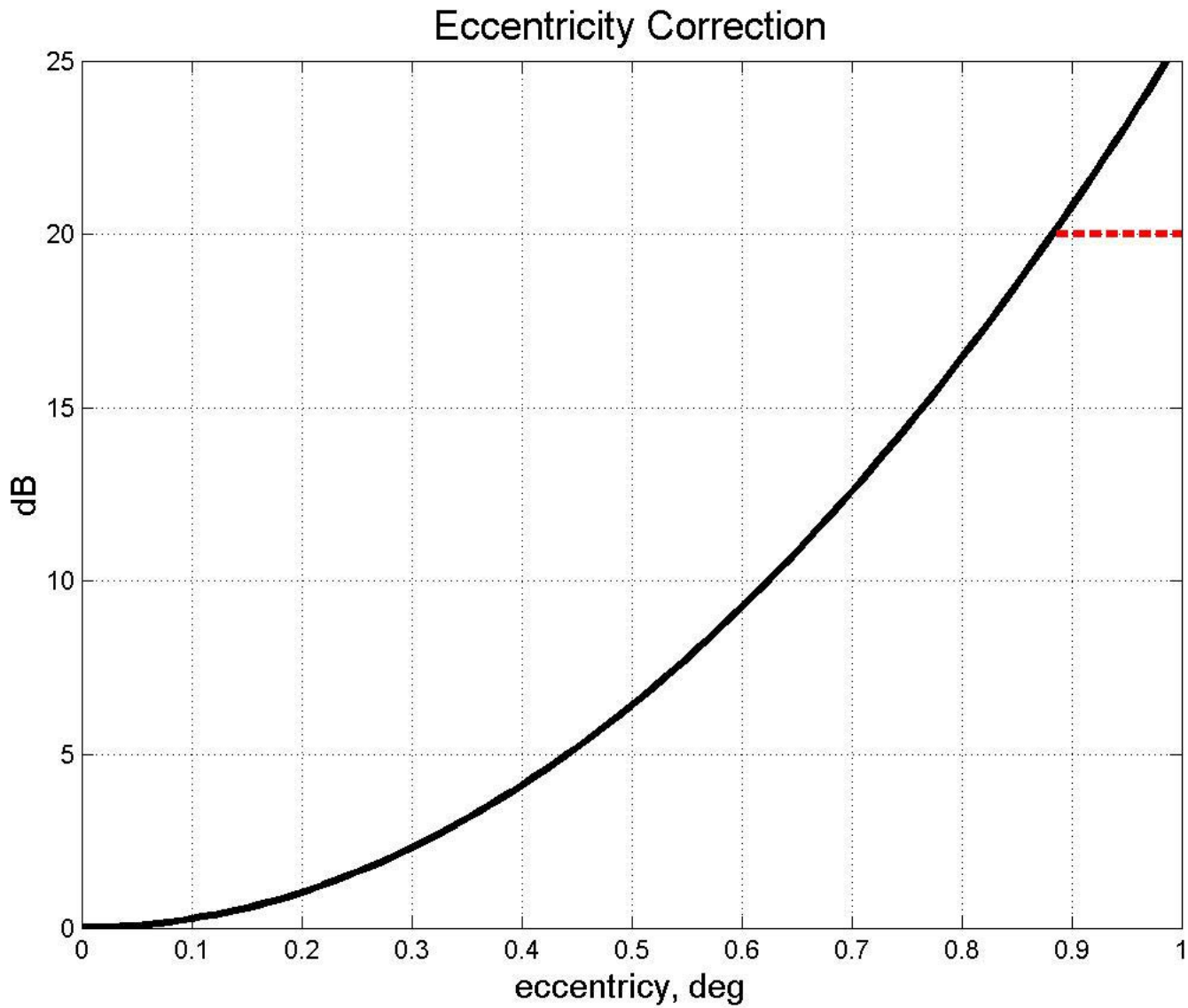
Eccentricity Correction

Contrast Gain Factor

$$-20 \log_{10} e^{-(e/w)^2}$$

$$w = 0.58 \text{ deg}$$

$$25.67\, e^2$$


Eccentricity Correction
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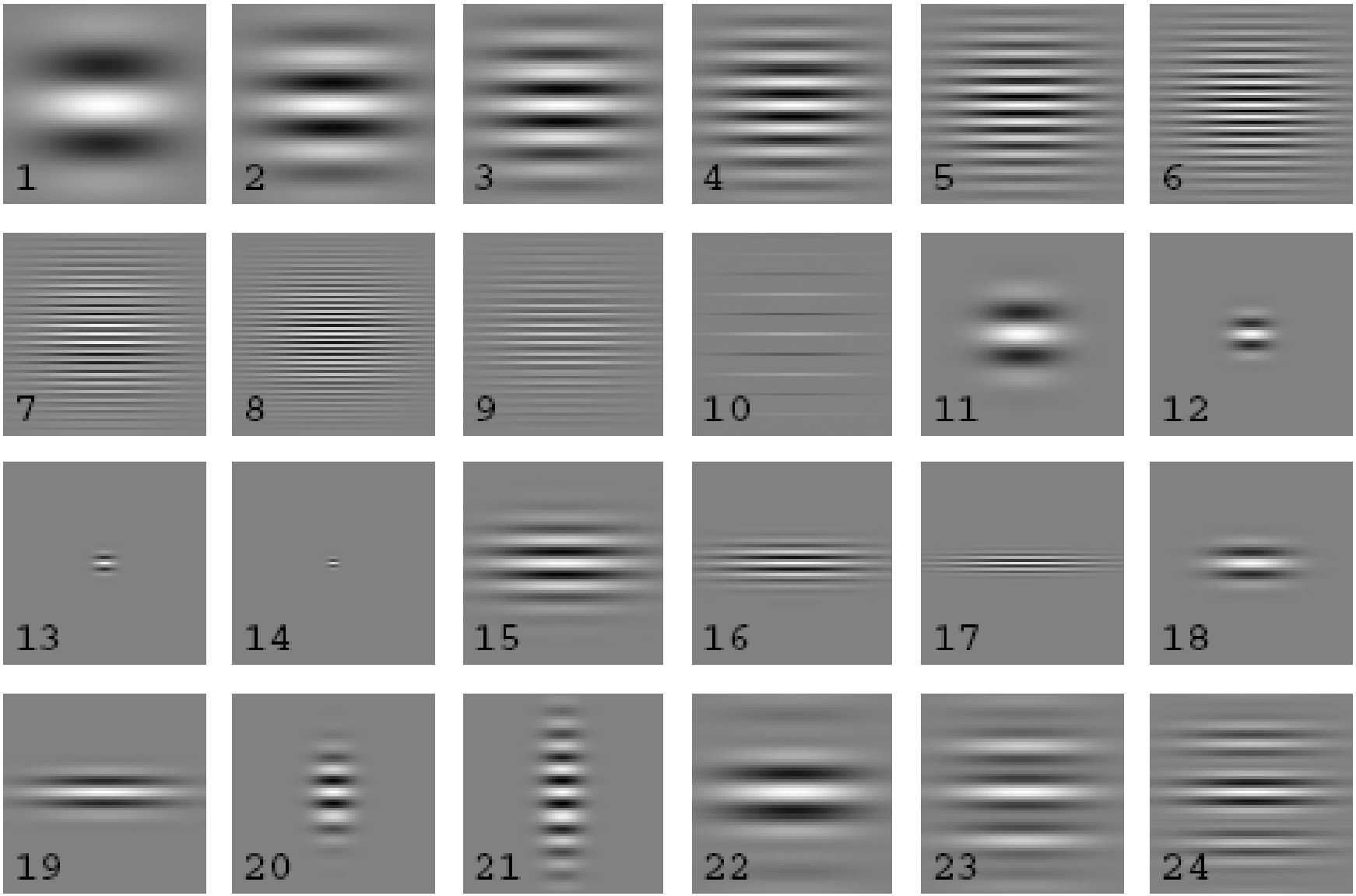
20
15
10
5
0
dB
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
eccentricy, deg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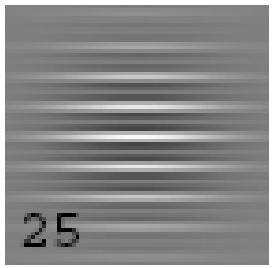
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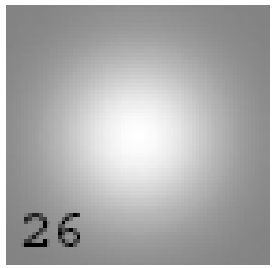
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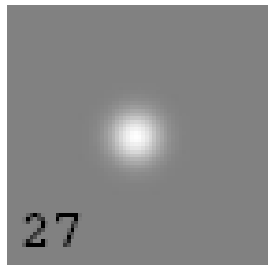
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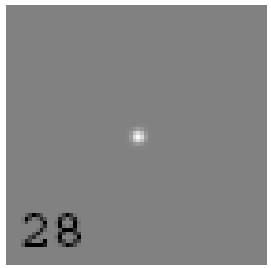
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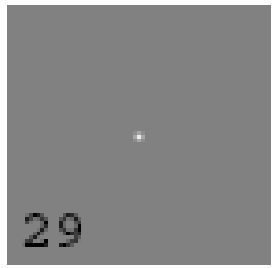
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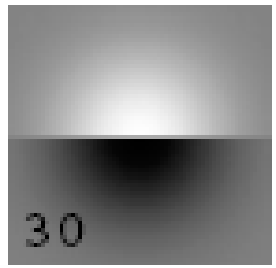
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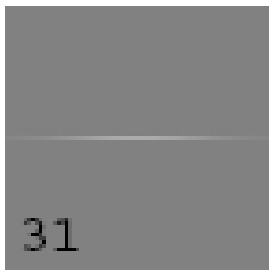
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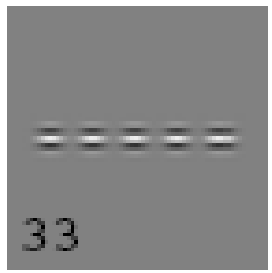
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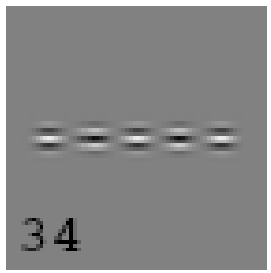
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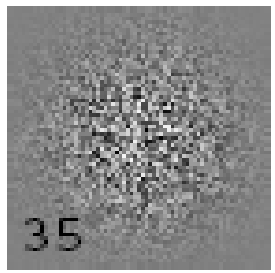
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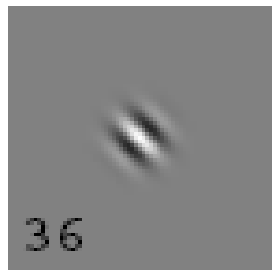
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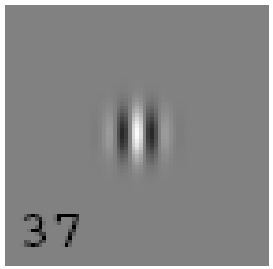
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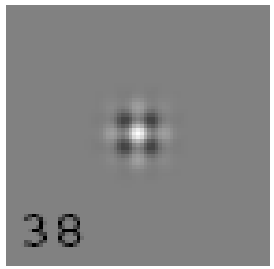
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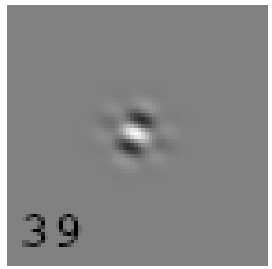
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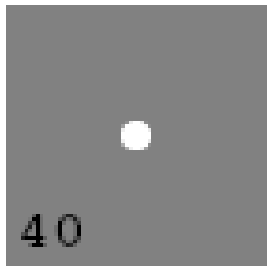
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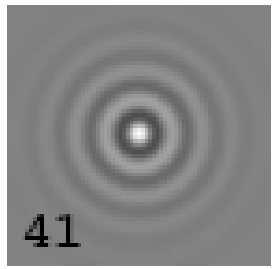
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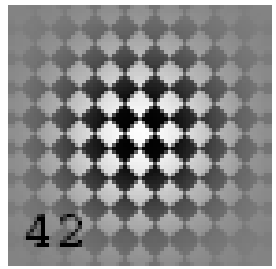
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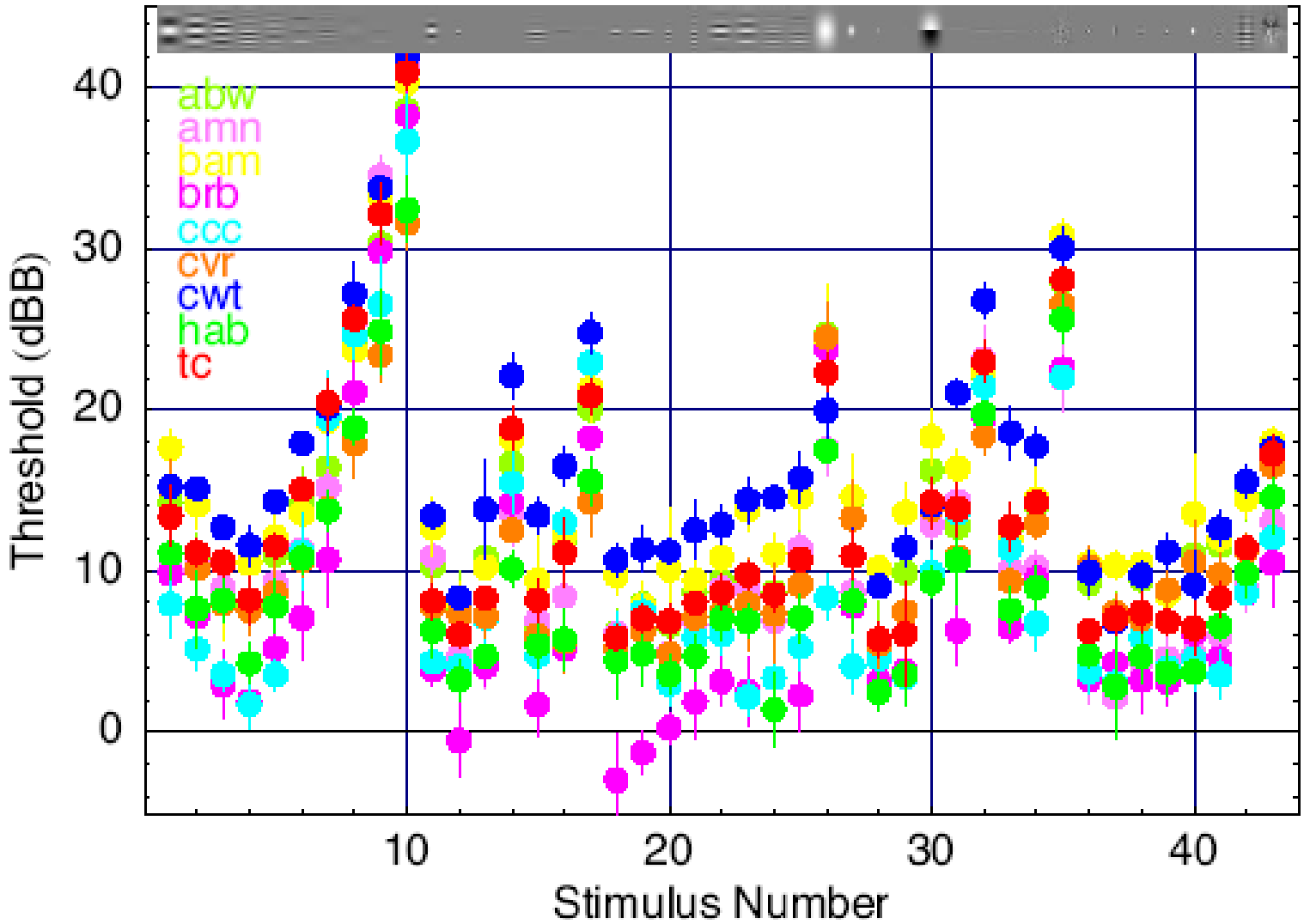
abw
amn
bam
brb
ccc
cvr
cwt
hab
tc
Threshold (dBB)
40
30
20
10
0
10
20
30
40
Stimulus Number

Error

RMS error in predicting the mean thresholds for 16 observers:

< 1 dB

(taking out a degree of freedom for each of the 5 parameters).

Observer by Stimulus Interaction RMS error:

0.45 dB

Discussion

The frequency correction is solid.
Watson and Ahumada (2004 VSS)
have the parameters for your favorite formula.

The ModelFest stimuli make it difficult to estimate an eccentricity effect in the presence of a best exponent.

We have corrections for orientation, masking, color CSF's.
They are based on much less extensive data, so we are trying to refine them.

DISCRIM

Michael Landy's Matlab program

Source, description, and manual at
www.cns.nyu.edu/~msl/**discrim**/

Reads or computes images,
allowing for gamma function, blur, noise.
Inputs for viewing parameters and model parameters
are flexible and default.
Uses generalized contrast energy model with simple
contrast gain masking to predict contrast threshold.