Modeling the interaction of two rapid adaptation processes: contrast comparison and contrast normalization

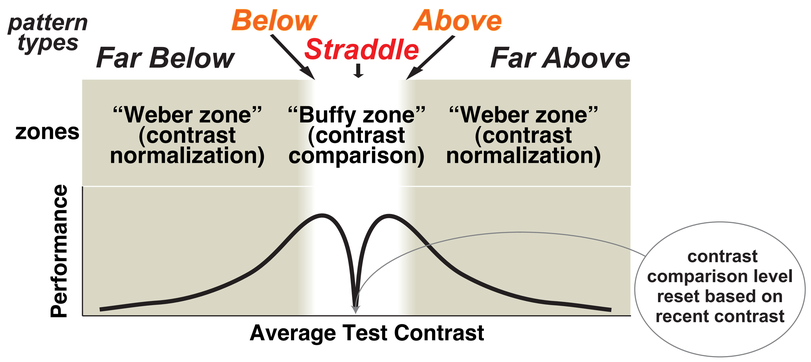
Norma Graham, S. Sabina Wolfson, Stephanie Pan, Gauri Wable, Ian Kwok & Boris Grinshpun *Columbia University, Dept of Psychology, New York, NY*

1 ~ Introduction

Contrast is important.
We spend most of our waking hours looking at patterned regions (non-zero contrast).
We spend very little time looking at un-patterned areas (zero contrast).

A few years ago we discovered a rather surprising effect of short-term adaptation to contrast: the **Straddle Effect**.

A **Straddle** test pattern is composed of two Test contrasts that straddle the Adapt contrast (one of the Test contrasts is below the Adapt contrast and the other is above it).
Example test patterns are shown under section "2 ~ Methods".
Performance is very poor on **Straddle** test patterns.
Performance is much better on **Below** and **Above** test patterns (the two Test contrasts are both below the Adapt contrast or both above it).
Performance declines again for Far Below and Far Above test patterns.

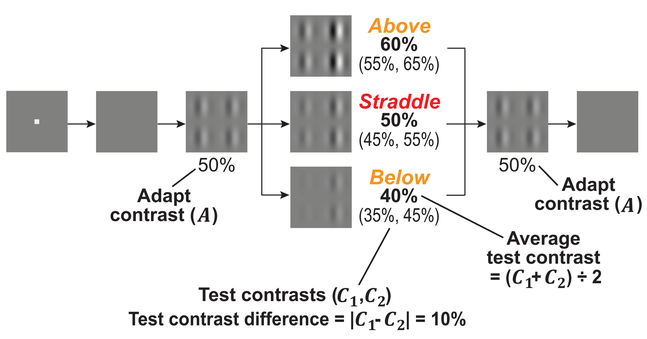


We suggest that two different processes/zones underlie performance...
In the center is the "Buffy zone" where contrast comparison produces the **Straddle Effect**.
At the ends is the "Weber zone" where contrast normalization produces Weber-like behavior.

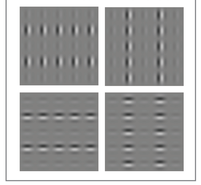
2 ~ Methods

Psychophysical trial with example contrast values

Fixation 1 sec → Gray 500 msec → Adapt 1 sec → Test 94 msec → After 1 sec → Gray 100+ msec

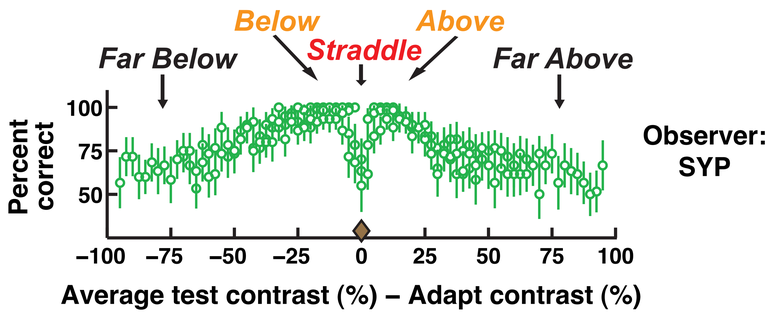


Task
Identify orientation of contrast-defined stripes in the test pattern

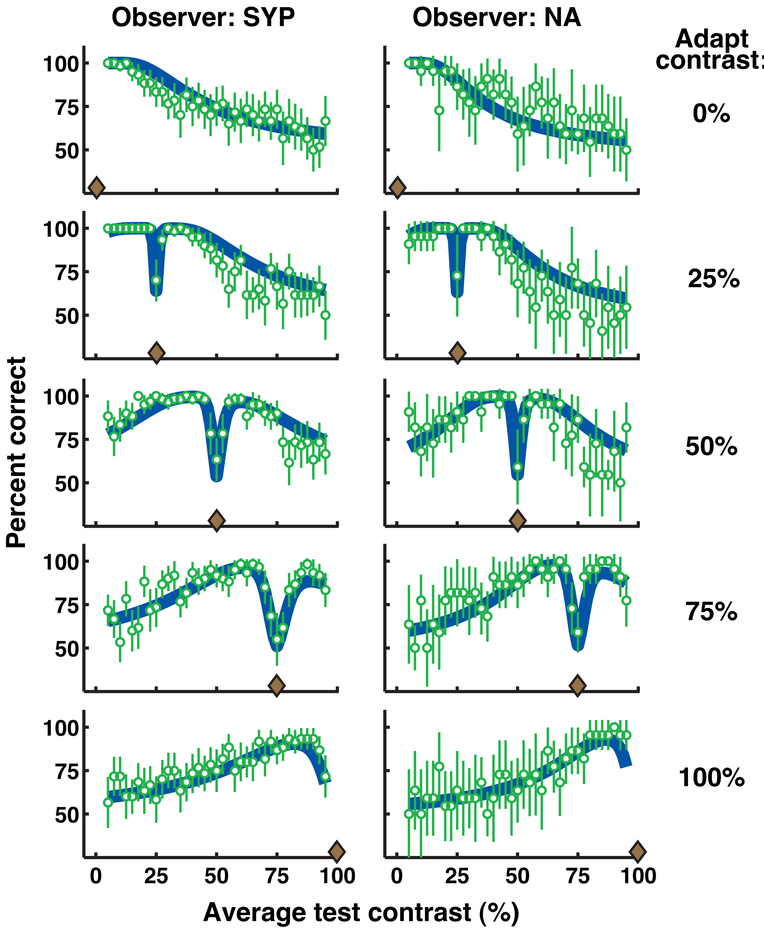


Some details of the methods...
- Observers were paid Columbia University undergraduates with normal or corrected-to-normal vision.
- Each pattern was a 2x2 grid of Gabor patches. We have also used a 15x15 and get the same results.
- The grid was centered at fixation and surrounded by a large gray field.
- Gabor patch orientation was the same through a trial.
- Gabor patch spatial frequency was about 2 cycle per deg at the viewing distance of 0.9 meters.
- The mean luminance was approx 50 cd/m^2.
- Observers were given feedback about correctness of their responses.

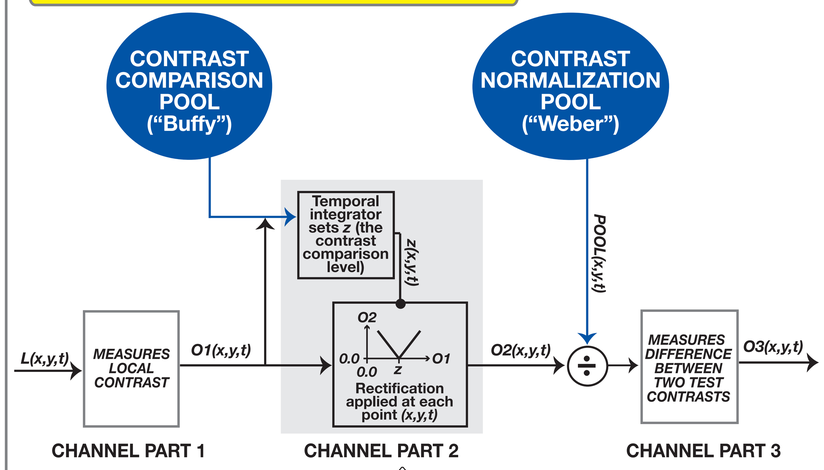
3 ~ Data & Predictions



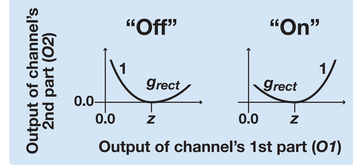
Data ± 2 SE
Predictions from model in section "4 ~ Model"
Adapt contrast



4 ~ Model



Rectification functions from a pair of otherwise-identical channels



g_{rect} = ratio of slopes
= 0 for half-wave
= 1 for full-wave
k_m = power in rectification function
O1, *O2*, and *z* are values at a particular *(x,y,t)*

For these experiments we assume $z = A$.

On-Off Pair of Channels Tuned to Pattern

$$R = \begin{cases} w \times \left(|\hat{C}_1|^{k_m} - |\hat{C}_2|^{k_m}\right) & Non\text{-}straddle \\ w \times max\left(\left||\hat{C}_1|^{k_m} - g_{rect} \times |\hat{C}_2|^{k_m}\right|, \left||\hat{C}_2|^{k_m} - g_{rect} \times |\hat{C}_1|^{k_m}\right|\right) & Straddle \end{cases}$$

Other Channels Monotonic with Contrast

$$R_O = w_O \times \left(|C_1|^{k_m} + |C_2|^{k_m}\right)$$

Other Channels Comparison Level = A

$$R_Z = w_Z \times \left(|\hat{C}_1|^{k_m} + |\hat{C}_2|^{k_m}\right)$$

Contrast Normalization Pool

$$POOL = \sigma + R_O + R_Z$$

Predicted Observer Internal Response

$$D_{OBS} = \frac{R}{POOL}$$

LIST OF SYMBOLS

C_1 and C_2 are the two Test contrasts.
A is the Adapt contrast.
$\hat{C}_1 = C_1 - A$ $\hat{C}_2 = C_2 - A$
g_{rect} = 0 (or 1) for half-wave (or full-wave) rectification.
k_m is the power of the rectification function.
R, R_O, and R_Z are the responses if there were no normalization.
w, w_O, and w_Z are the corresponding weights (sensitivities).
R is from the On-Off Pair of channels tuned to the pattern.
R_O is from the group of other channels that respond monotonically to physical contrast.
R_Z is from the group of other channels for which the comparison level = A.
$POOL$ is the normalization pool's response.
σ is the parameter of the normalization pool.
D_{OBS} is the variable on which the observer's response is based.

5 ~ Conclusions & Speculations

The model in section "4 ~ Model" explains well both the steady-state **Straddle Effect** and the Weber-like behavior.

The experimental and modeling results together suggest that...

The important quantity in much human contrast processing is <u>not</u> monotonic with physical contrast.

It is more like the (un-signed) difference between the current contrast and the recent average contrast.

Society for Neuroscience 2009 Program#/Poster#: 651.14/Y7
Norma Graham nvg1@columbia.edu www.columbia.edu/~nvg1
Sabina Wolfson sabina@psych.columbia.edu www.columbia.edu/~sw354