



# On the Perception of Brightness and Contrast of Variegated Backgrounds

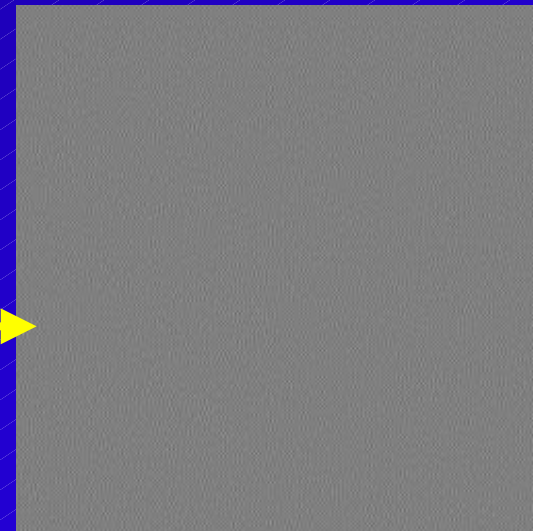
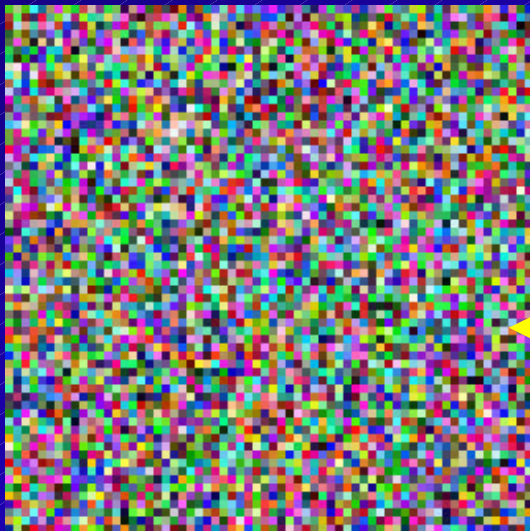
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# Objectives

- **Examination of the Appearance of Spatially Complex Stimuli**
- **Possible Derivation of a “Spatial Integration Function” for use in Color Appearance Models**





# Outline

- **Background**
- **Previous Research**
- **Experimental Design**
  - **Results**
- **Conclusions**



# Need for Adaptation Point in CIECAM97s

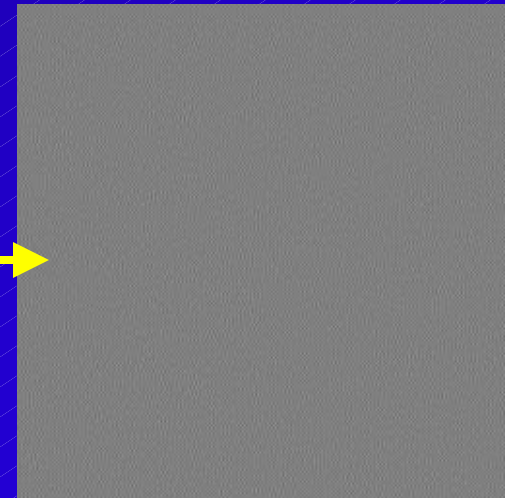
$X_w Y_w Z_w$ : Tristimulus Values of White

Obtained From: Light Source, Paper White, Display White Point, *etc.*

How Obtained for Complex Adapting Fields?



VS.



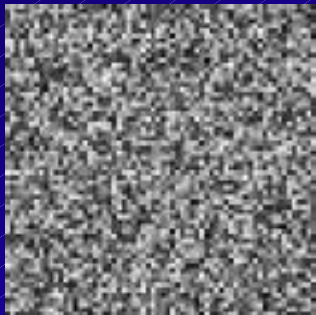


# Background: Oskoui & Pirrotta CIC6 Results

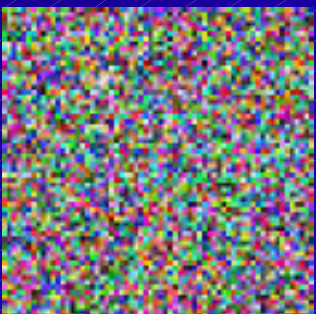
P. Oskoui & E. Pirrotta, Influence of Background Characteristics on Adapted White Points of CRTs, *IS&T/SID 6th Color Imaging Conference*, 22-26 (1998).



**Adaptation to various backgrounds all integrating to monitor white point.**



**Uniform Gray & Achromatic Random Dots:  
Similar Adaptation Level**



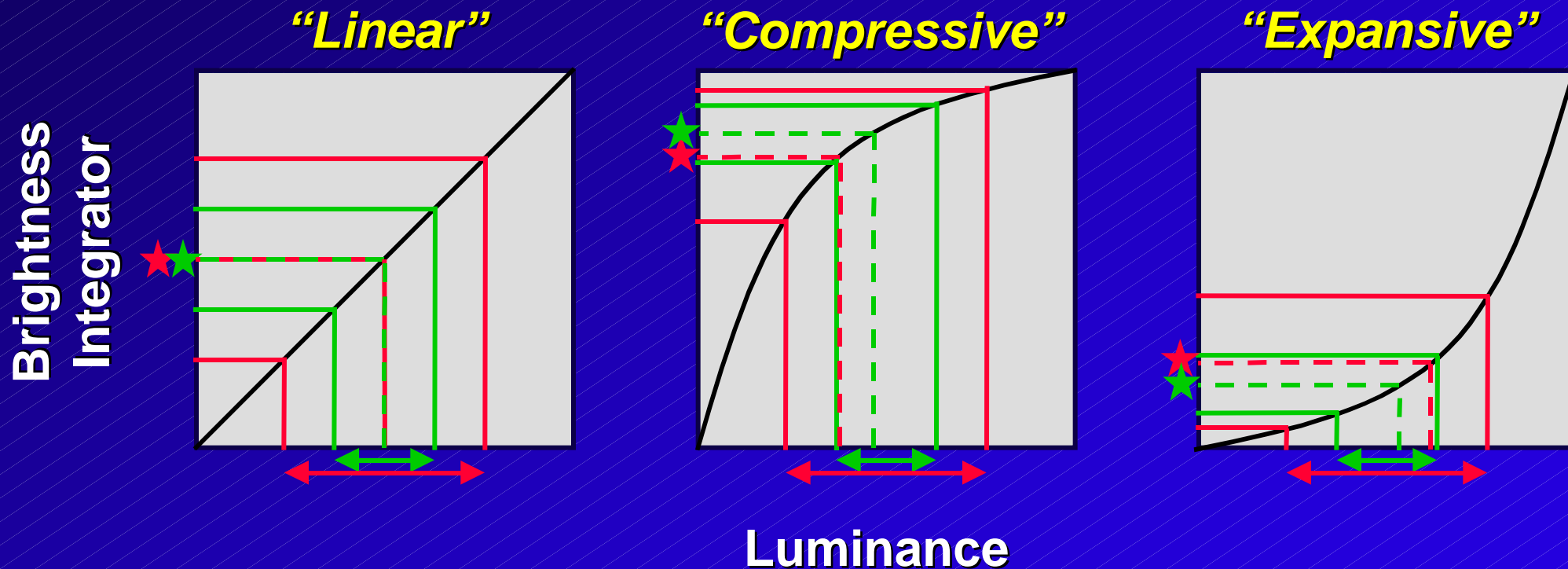
**Chromatic Random Dots:  
Less Complete Adaptation,  
More Observer Variability**





# An Integration Hypothesis

If the visual system integrates the adapting background using a nonlinear transform of luminance, the Oskoui & Pirrotta results could be obtained.







## Some Anecdotal Support

*The potency of this influence of comparison in perception is well illustrated by the illusion of heightened luminance in scenes where brightness differences are large, and the illusion of lowered luminance in scenes where the brightness differences are small. As a consequence of this effect, which leads to erroneous judgements of scene luminance, photographers sometimes unintentionally underexpose a “contrasty” theatrical scene indoors but overexpose a dull flat scene outdoors.*

*-OSA, The Science of Color, p. 154 (1963).*





# An Experiment to Test It: Brightness Matching

If perceived overall brightness of variegated stimuli (that integrate to constant luminance) is a function of contrast, then a nonlinear integration function could be derived.





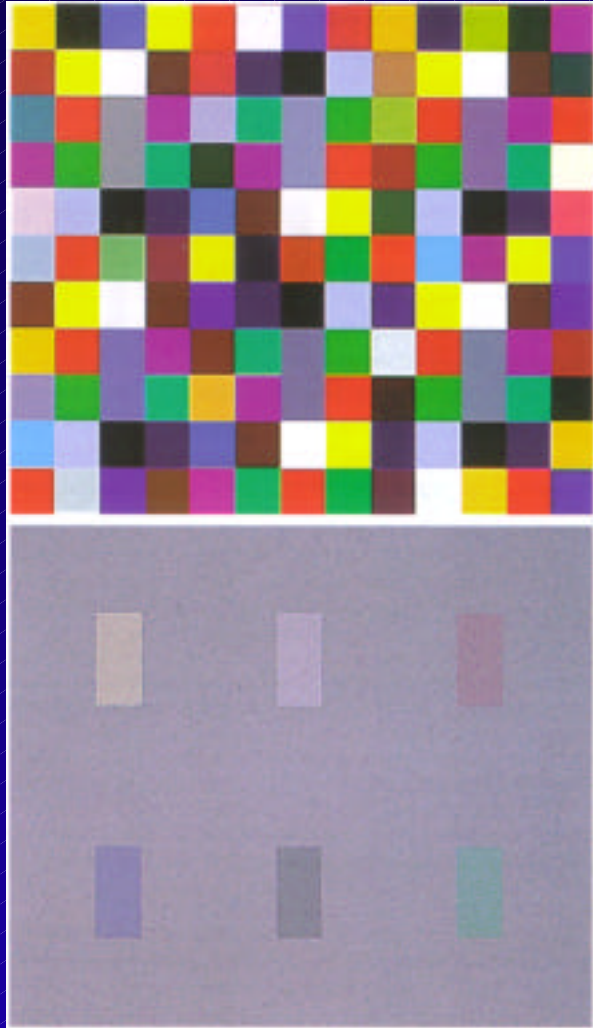
# A Secondary Effect: Contrast

**Does the apparent lightness of a patch on a variegated background track with the brightness-contrast relationship? (*i.e.*, simultaneous contrast with the equivalent background)**





# Previous Work: Brown & MacLeod

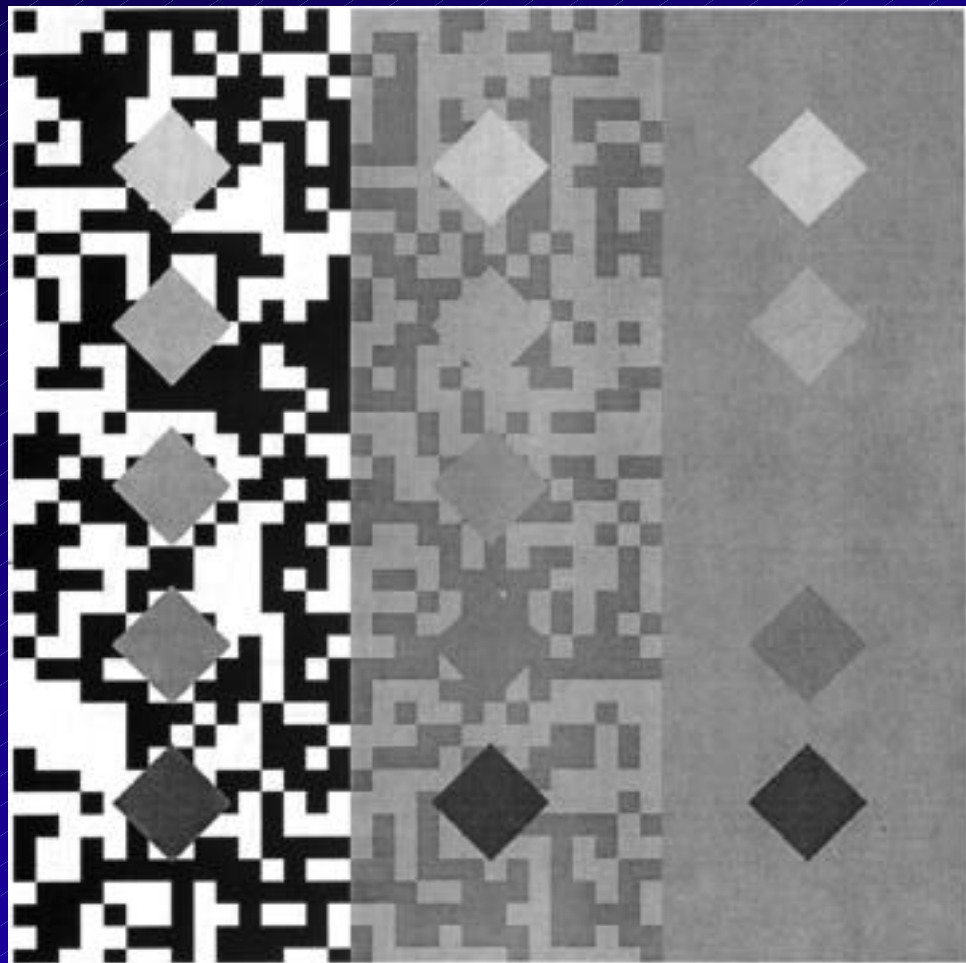


R.O. Brown & D.I.A. MacLeod, Color Appearance Depends on the Variance of Surround Colors, *Current Biology* 7, 844-849 (1997).

- Color Appearance Depends on Mean *AND* Variance of Background
- Contrast in Background Reduces Contrast of Stimuli



# Previous Work: Zaidi *et al.*



B. Spehar, J.S. DeBonet & Q. Zaidi,  
Brightness Induction from Uniform  
and Complex Surrounds: A General  
Model, *Vision Res.* 36, 1893-1906  
(1996).

- **Contrast Gain Control (Adaptation)**
- **Contrast in the Background Reduces Contrast of Test Patches**



# Previous Work: Adelson

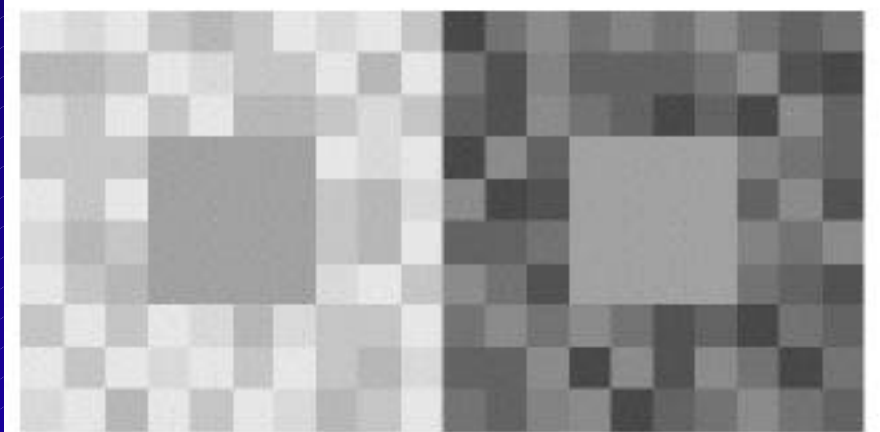
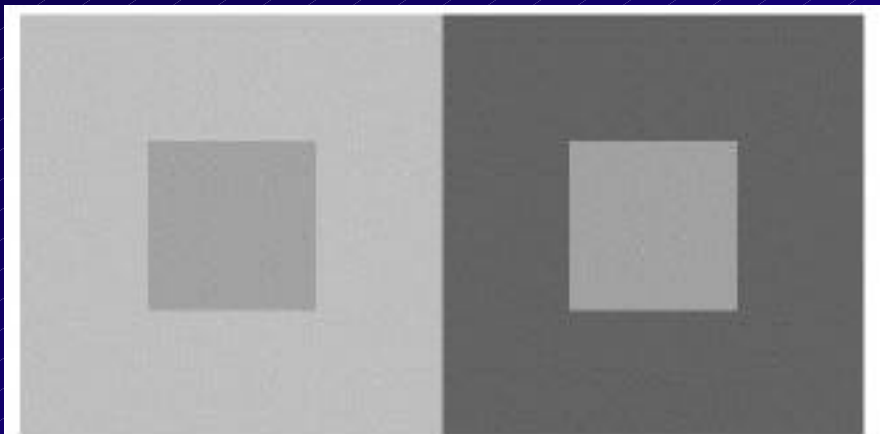


Figure 11: Simultaneous contrast is enhanced with articulated surrounds, as shown below.

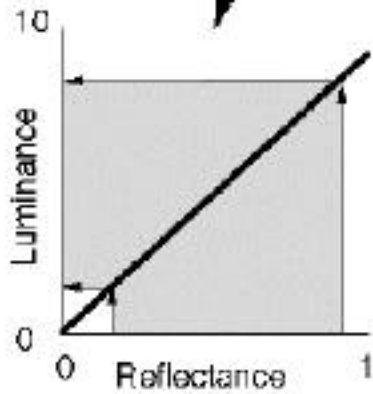
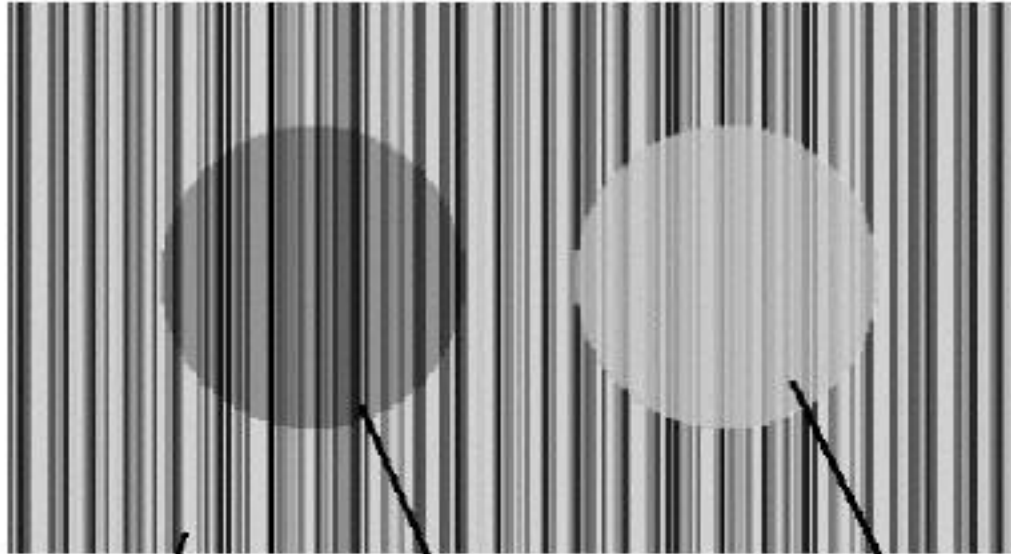
E.H. Adelson, *Lightness Perception and Lightness Illusions*, in *The Cognitive Neurosciences 2nd Ed.*, MIT Press (1999).

- **Atmospheric Transfer Function**  
(*luminance*  $\leftrightarrow$  *perceived reflectance*)
- **Can be either contrast gain or contrast adaptation, depending on stimulus configuration.**

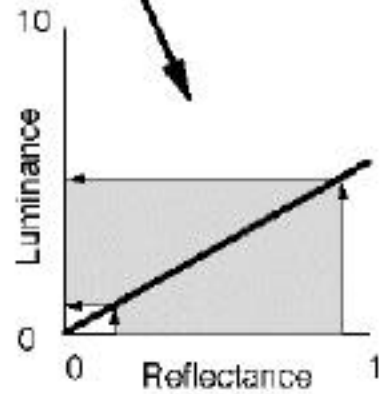




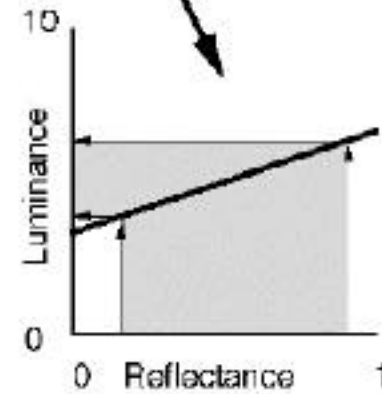
# Adelson's Atmospheric Transfer Function



a



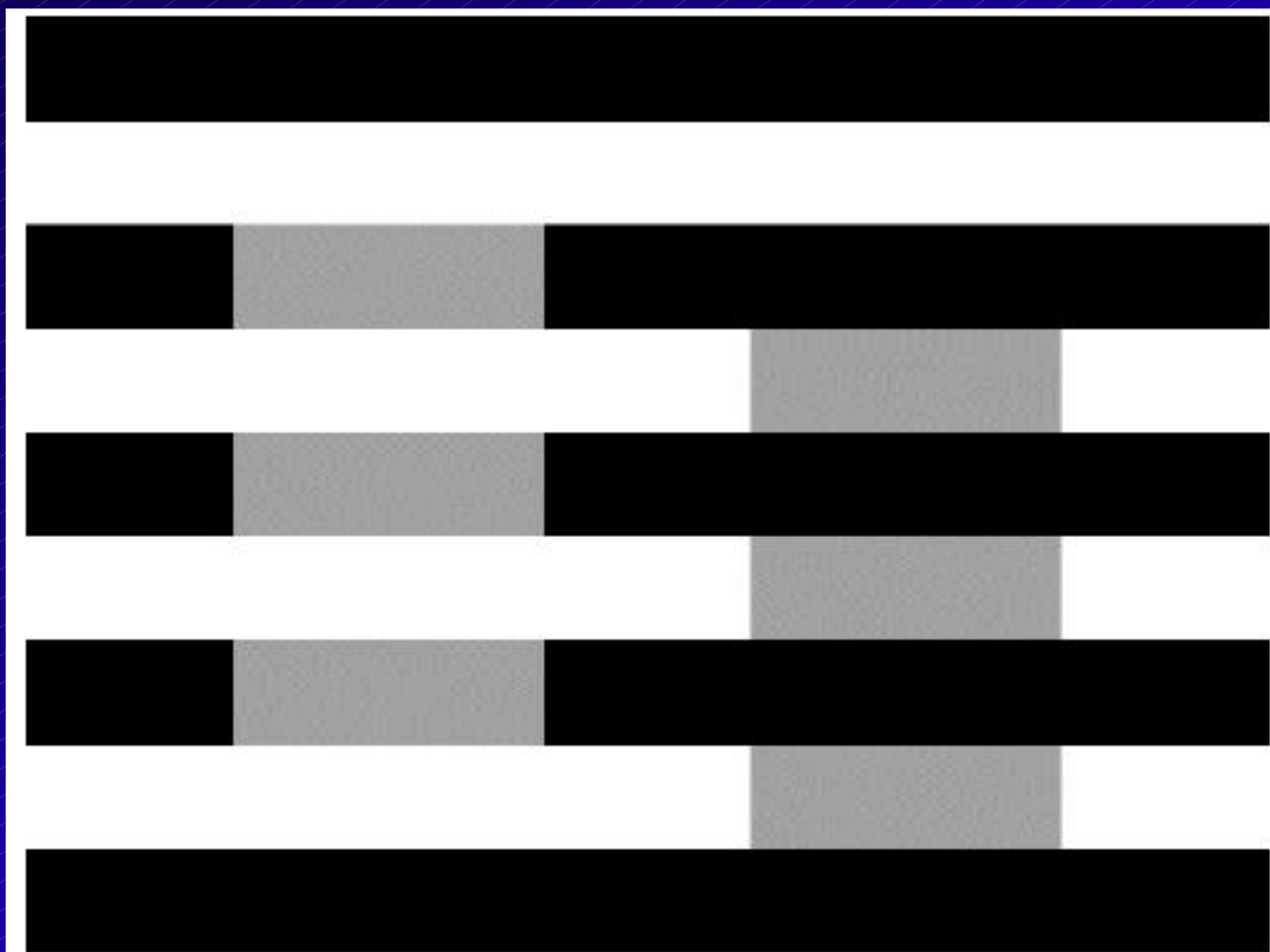
b



c



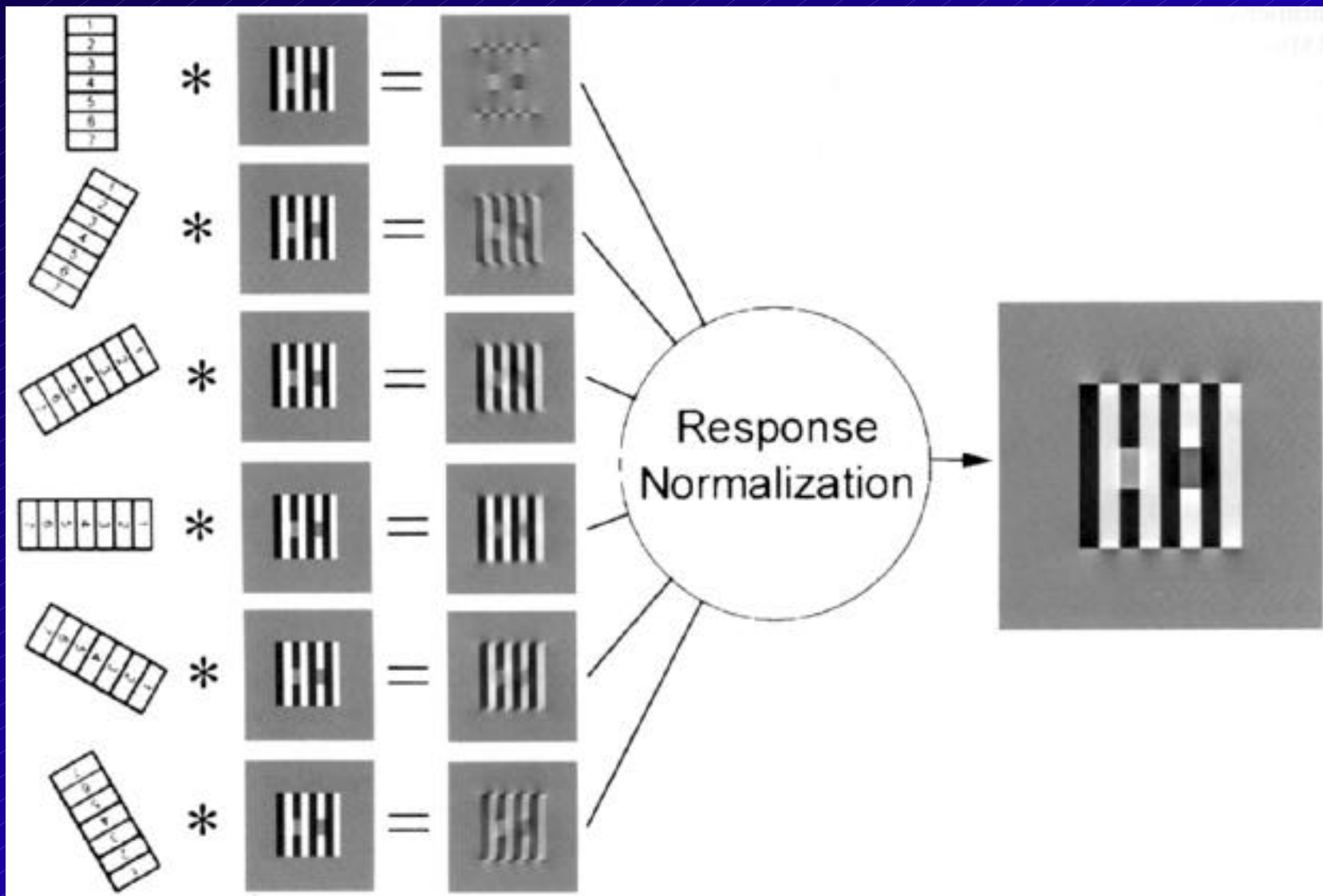
# Another Type of Example



*Figure 18: White's illusion. The gray strips are all the same shade of gray.*

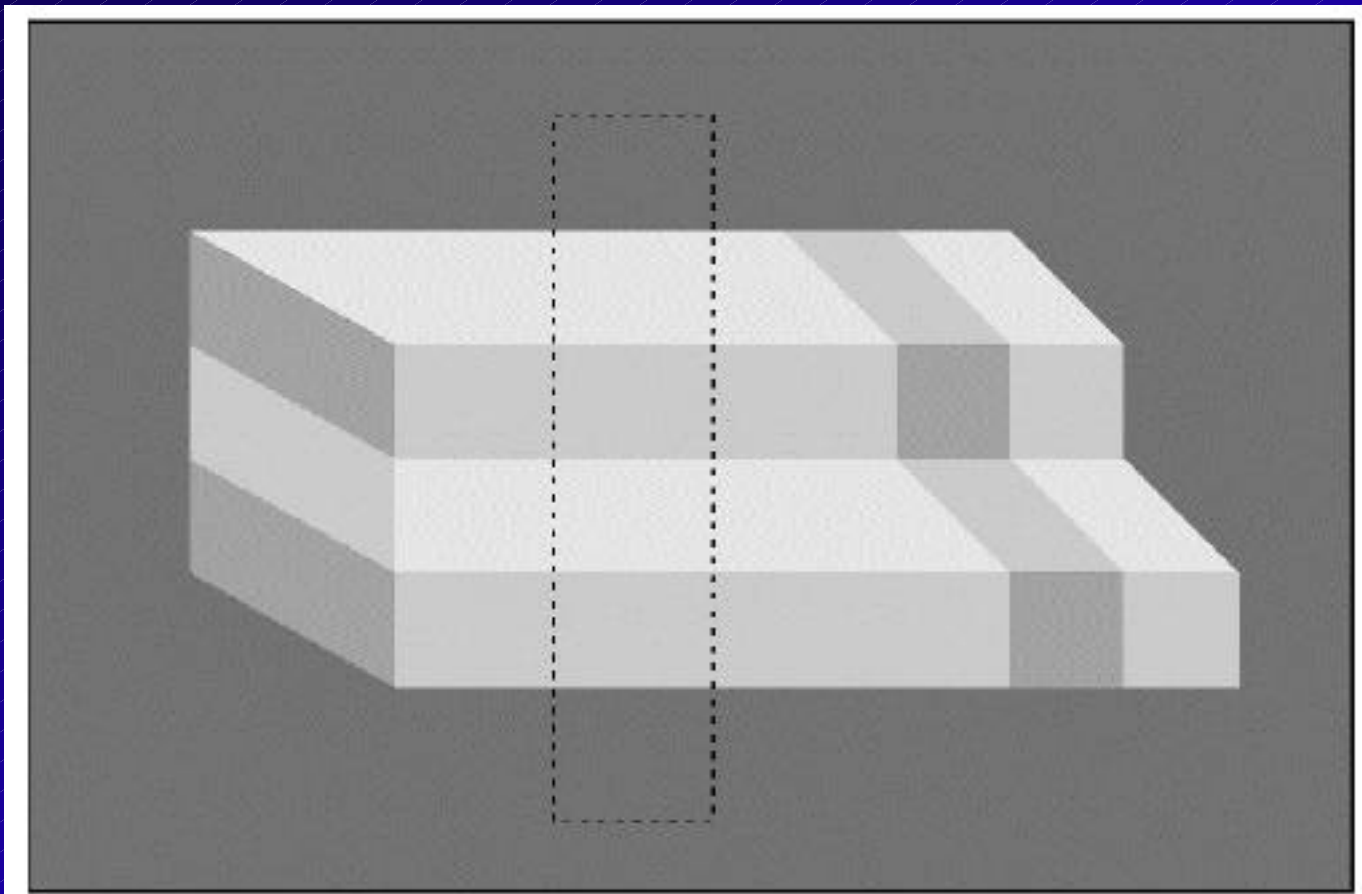


# A Simpler Explanation?





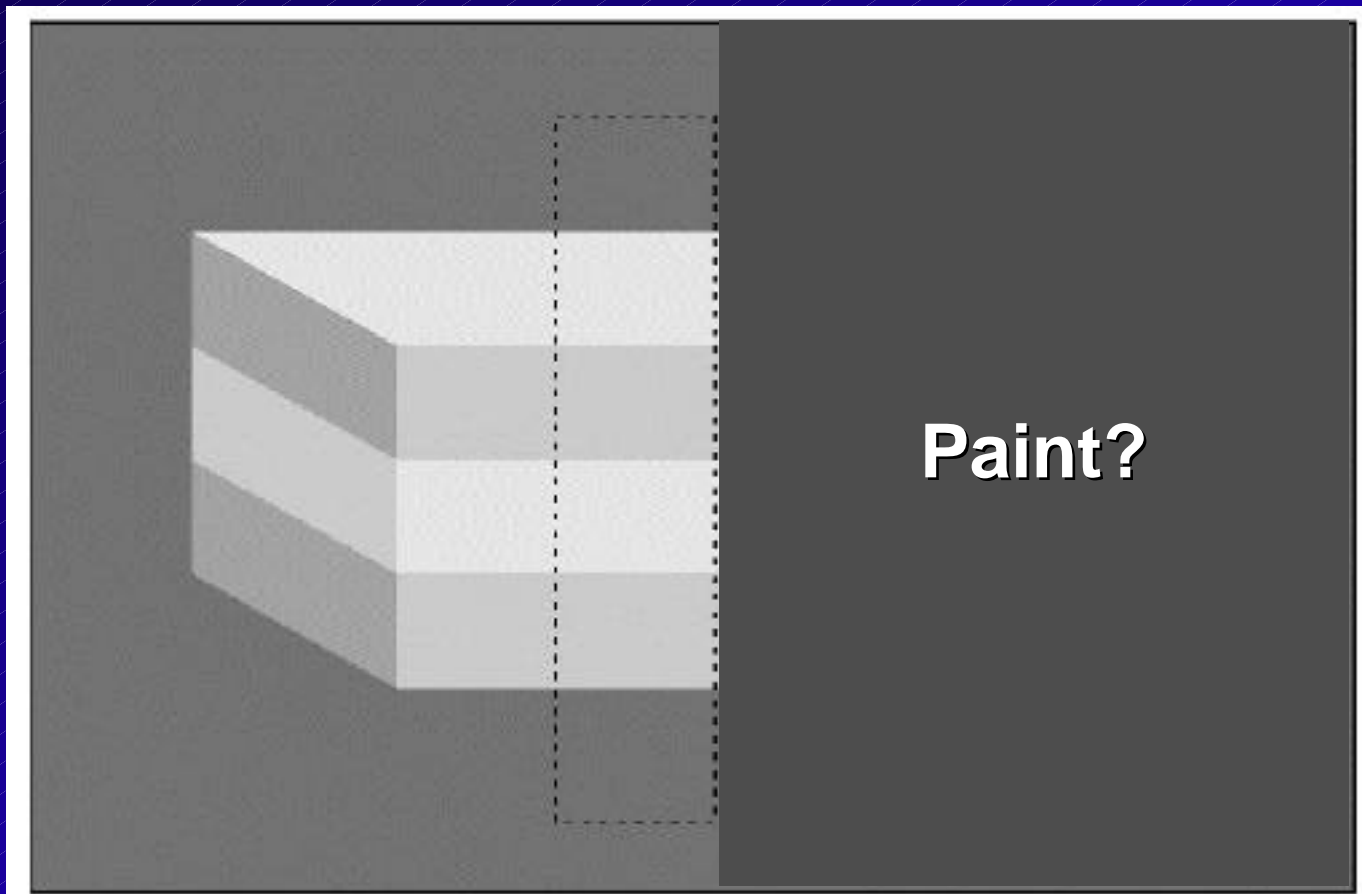
# Another Fun Example from Adelson



*Figure 9: The impossible steps. On the left, the horizontal strips appear to be due to paint; on the right, they appear to be due to shading.*



# Another Fun Example from Adelson

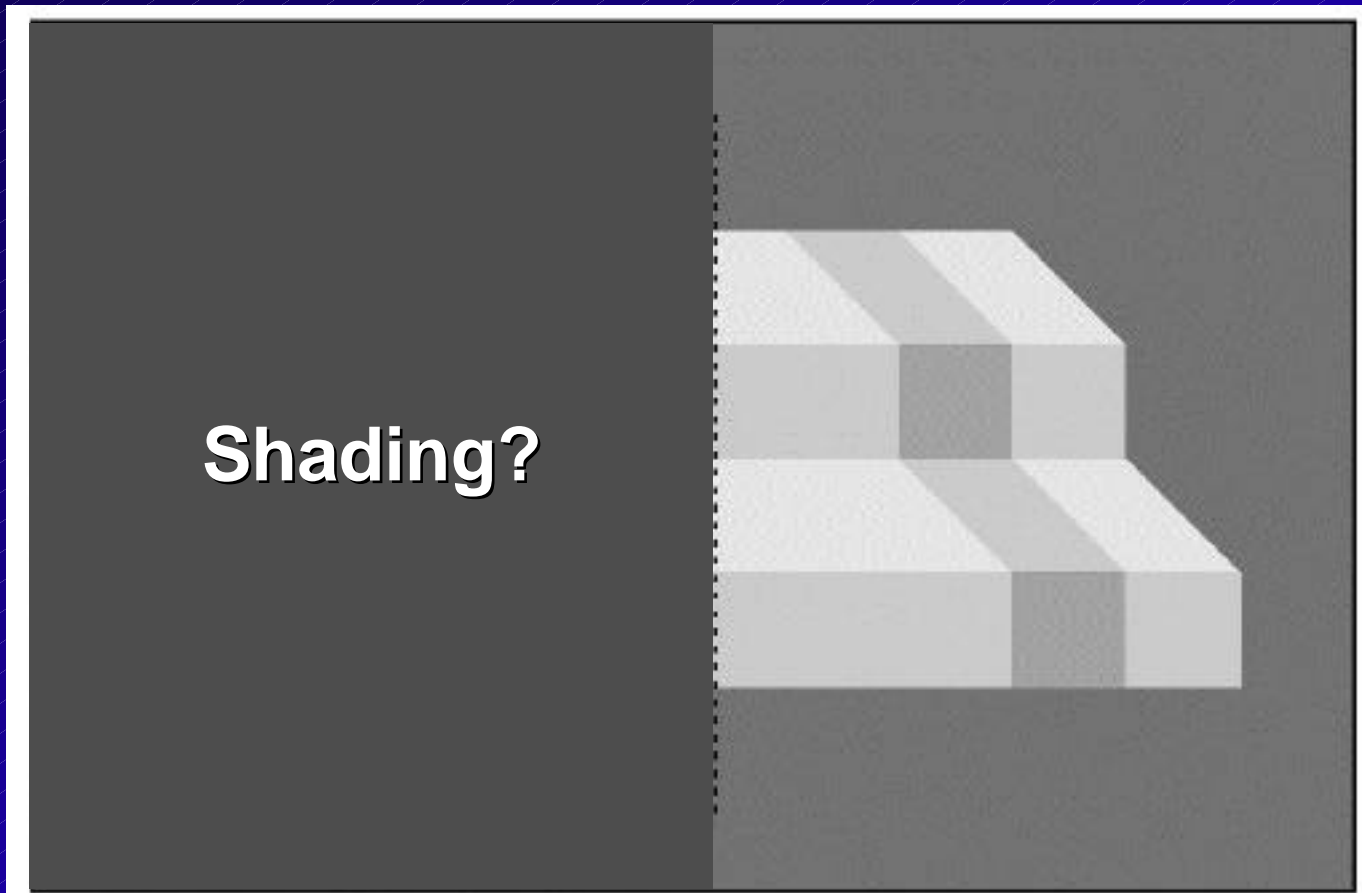


*Figure 9: The impossible steps. On the left, the horizontal strips appear to be due to paint; on the right, they appear to be due to shading.*





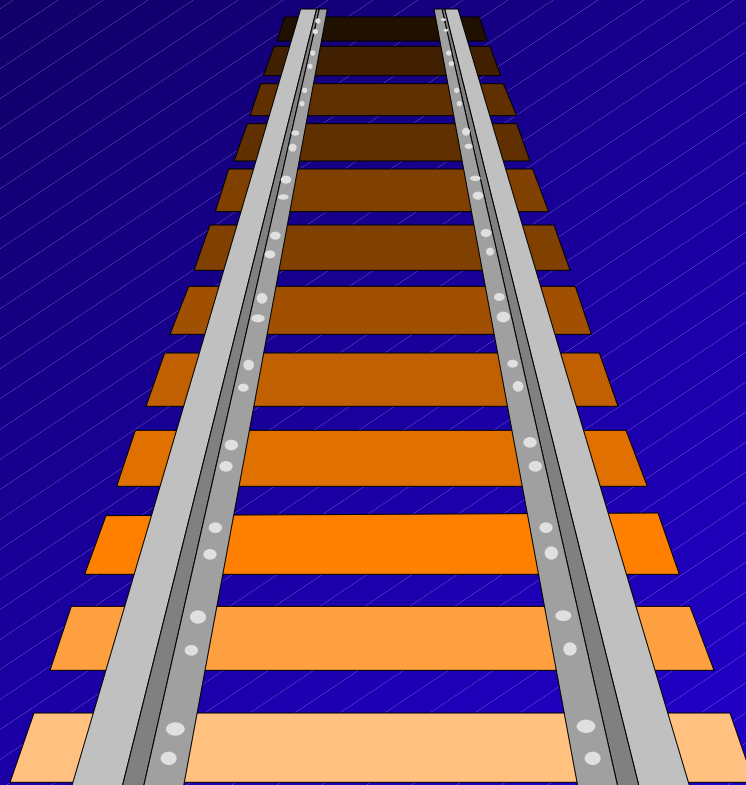
# Another Fun Example from Adelson



*Figure 9: The impossible steps. On the left, the horizontal strips appear to be due to paint; on the right, they appear to be due to shading.*



# Back to the Main Point...

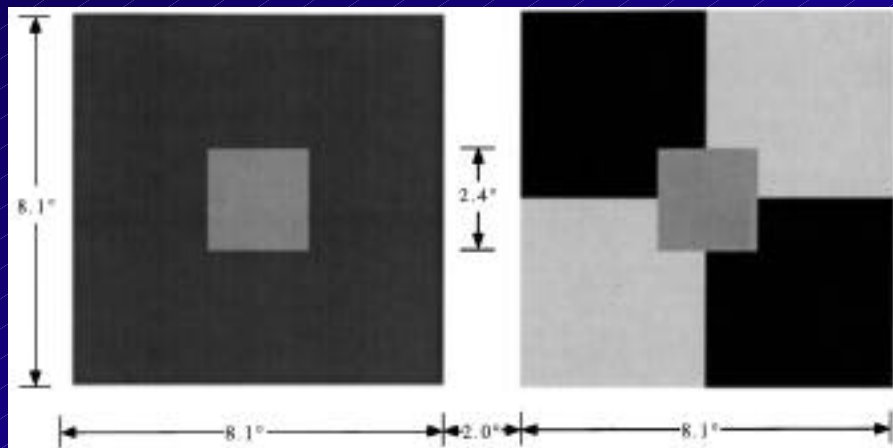


**Is there a simple relationship between image contrast and perceived brightness?**



# Previous Work: Schirillo & Shevell

J.A. Schirillo & S.K. Shevell, Brightness Contrast from Inhomogeneous Surrounds, *Vision Res.* 36, 1783-1796 (1996).

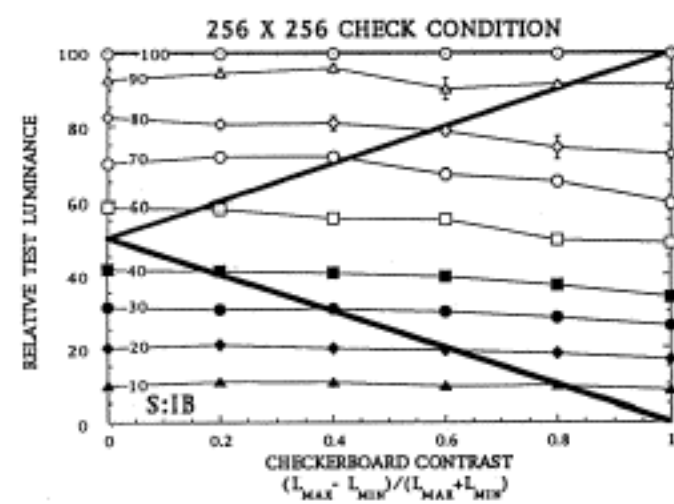
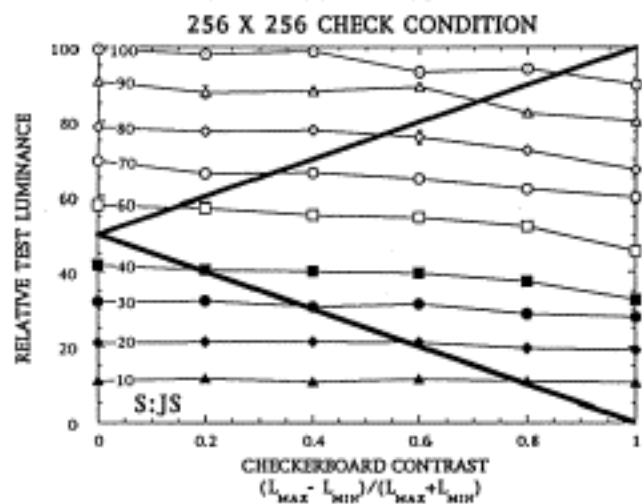
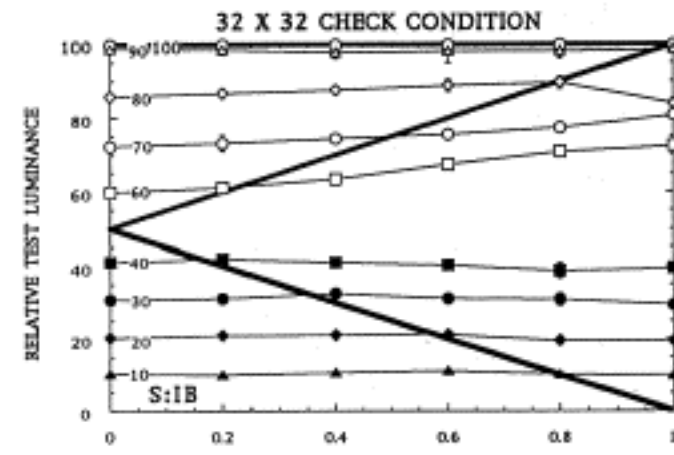
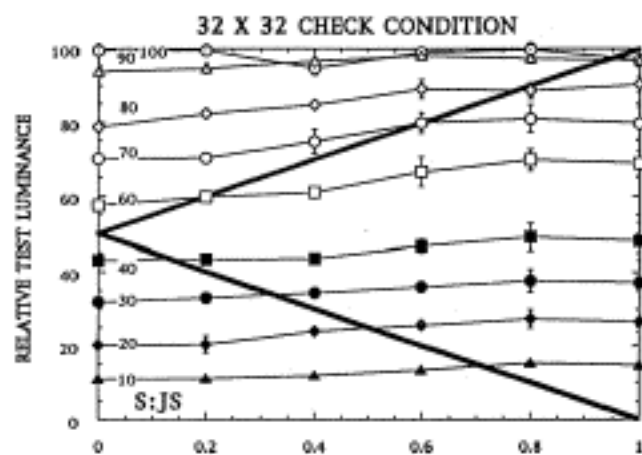
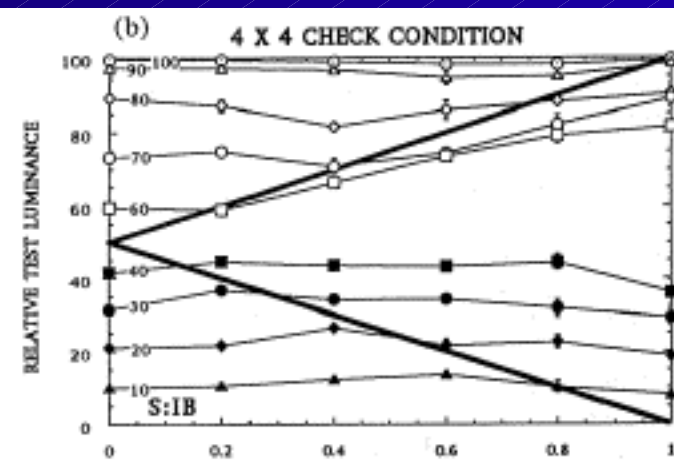
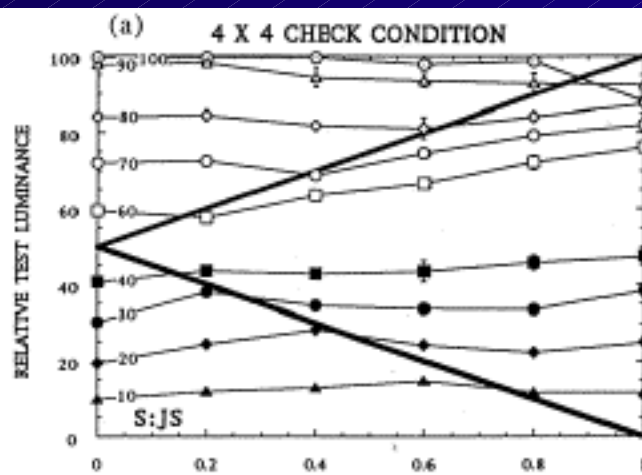


(Examined 2x2, 4x4, 32x32,  
& 256x256 Backgrounds)

- **Enhanced Contrast with Background Contrast for Increments**
- **No Effect for Decrements**
- **Dependency on Background Configuration**



# Schirillo & Shevell Results





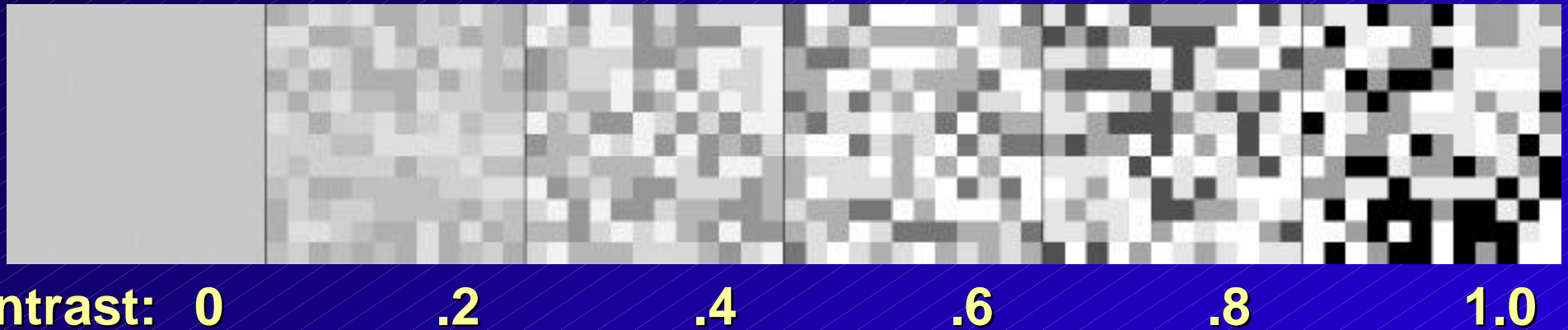
# Summary of Previous Work

- **Apparently Contradictory**
- **Contrast Adaptation** (Brown & MacLeod, Zaidi *et al.*)
- **Contrast Gain** (Adelson, Schirillo & Shevell)
- **Higher Level Effect, Atmosphere** (Adelson)
- **Sometimes No Effect** (Schirillo & Shevell)
- **Different Stimulus Configurations & Tasks**





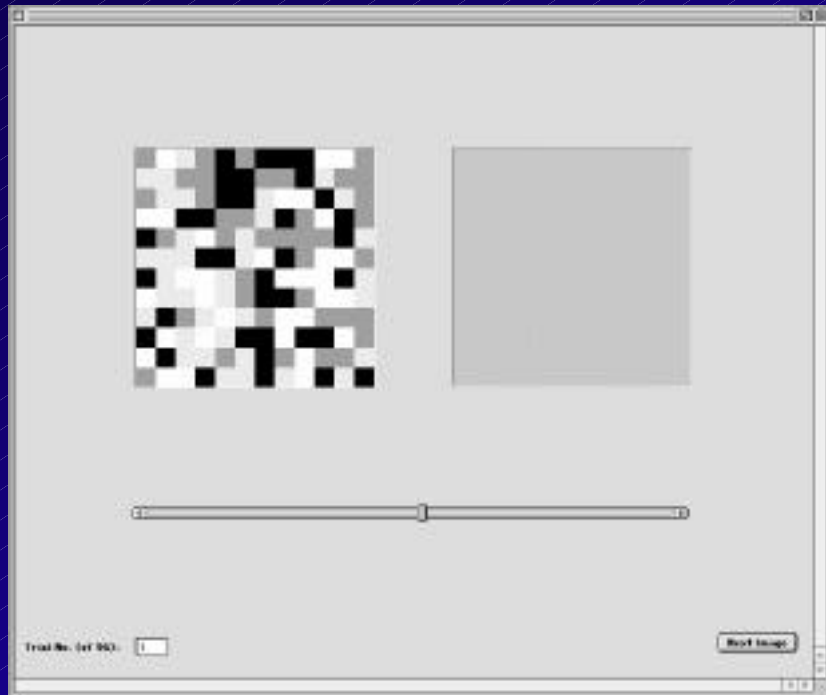
# Experimental: Background Images



- **4 Gray Levels Equally Spaced in Luminance**
- **All Integrate to Relative Luminance of 0.5**  
(Verified Instrumentally)
- **Monochrome to Isolate Integration Effect**
- **Randomly Generated on Each Trial**



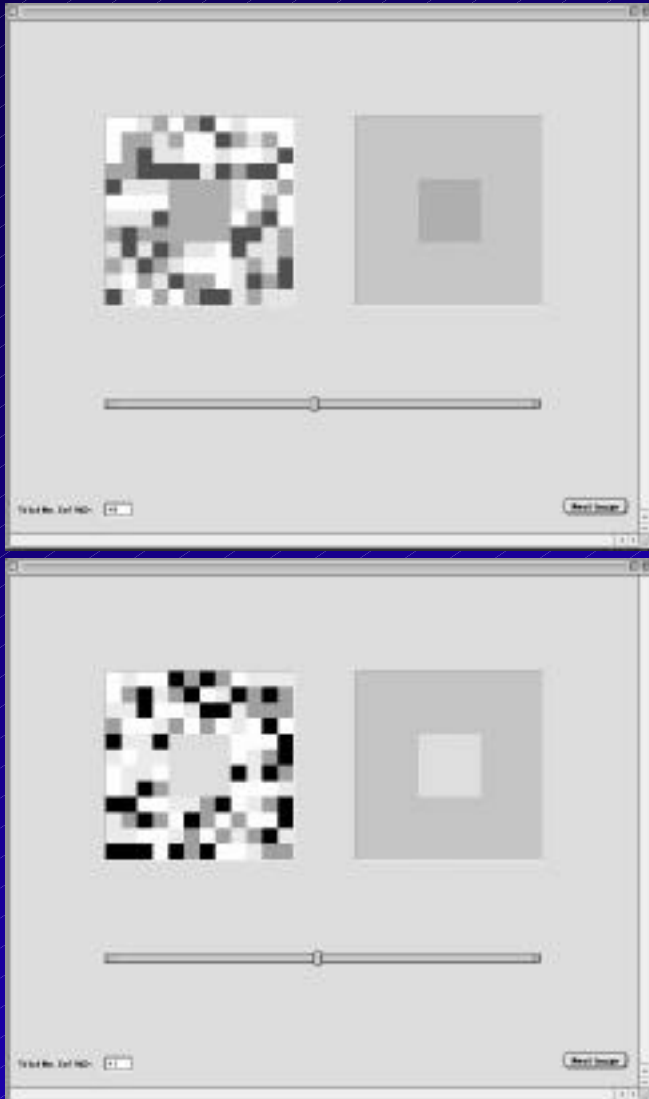
# Experimental: Brightness Task



- **Adjust Uniform Patch to Match Perceived Overall Brightness of Left Field**
- **Each Contrast Level Presented 5 Times for a Total of 30 Trials**
- **Slider Values and Start Point Randomized**
- **Trials Randomized**
- **4° Stimuli**



# Experimental: Contrast Tasks



- **Adjust Uniform Background to Match Brightness of Central Stimuli**
- **Stimulus Relative Luminances of 0.4 & 0.6 Used**
- **Each Contrast Level Presented 5 Times for a Total of 60 Trials**
- **Again Complete Randomization**
- **1° Patches on 4° Backgrounds**

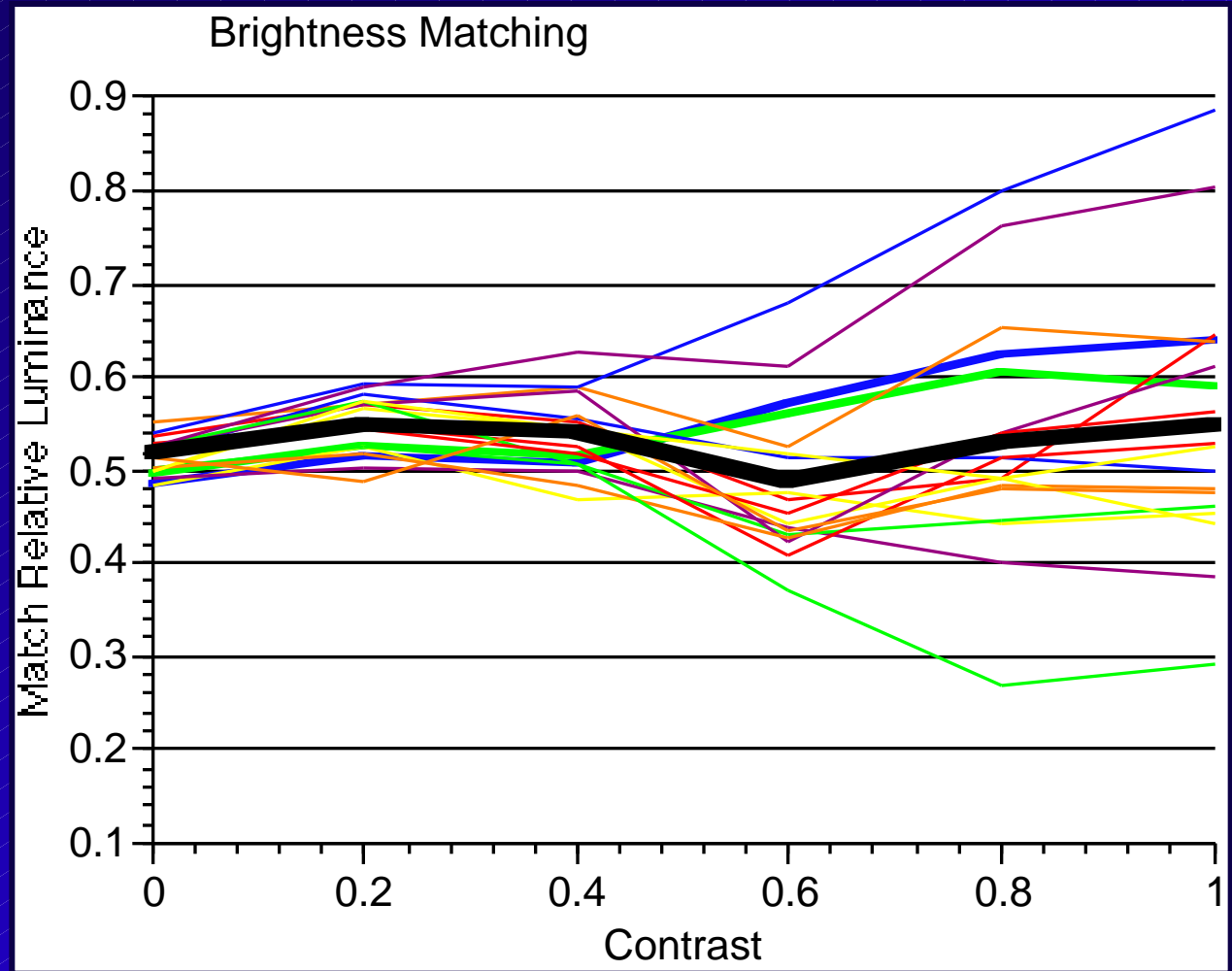
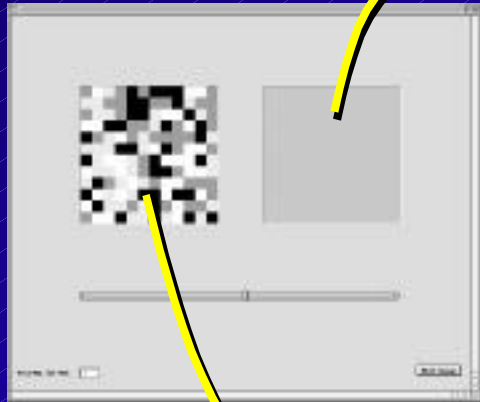


# Experimental Setup & Observers

- **Sony GDM-2000TC (Instrumentally Linearized)**
- **97 cd/m<sup>2</sup> D93 White**
- **Background Sub-Squares ~ 1/3°**
- **Fully Darkened Room**
- **17 Observers (23-40 Years, Experienced)**
- **6 Practice Trials First**



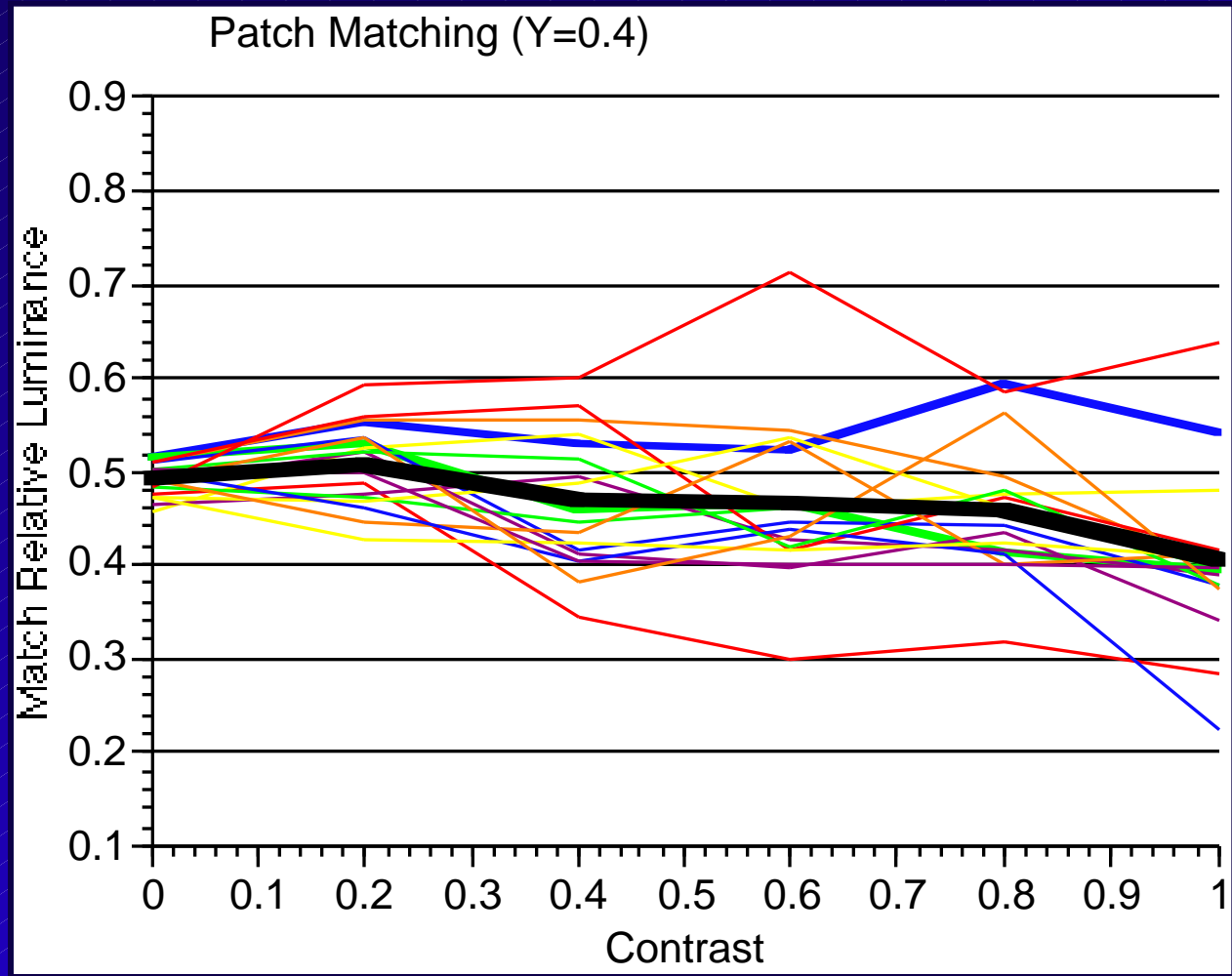
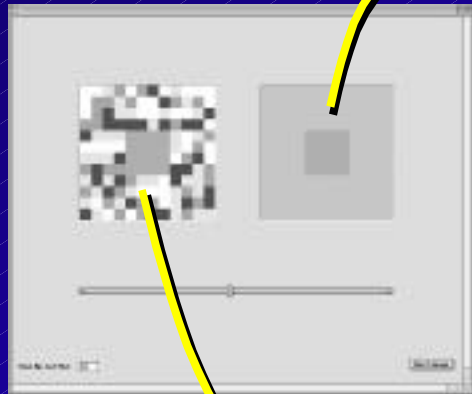
# Results: Brightness Matching





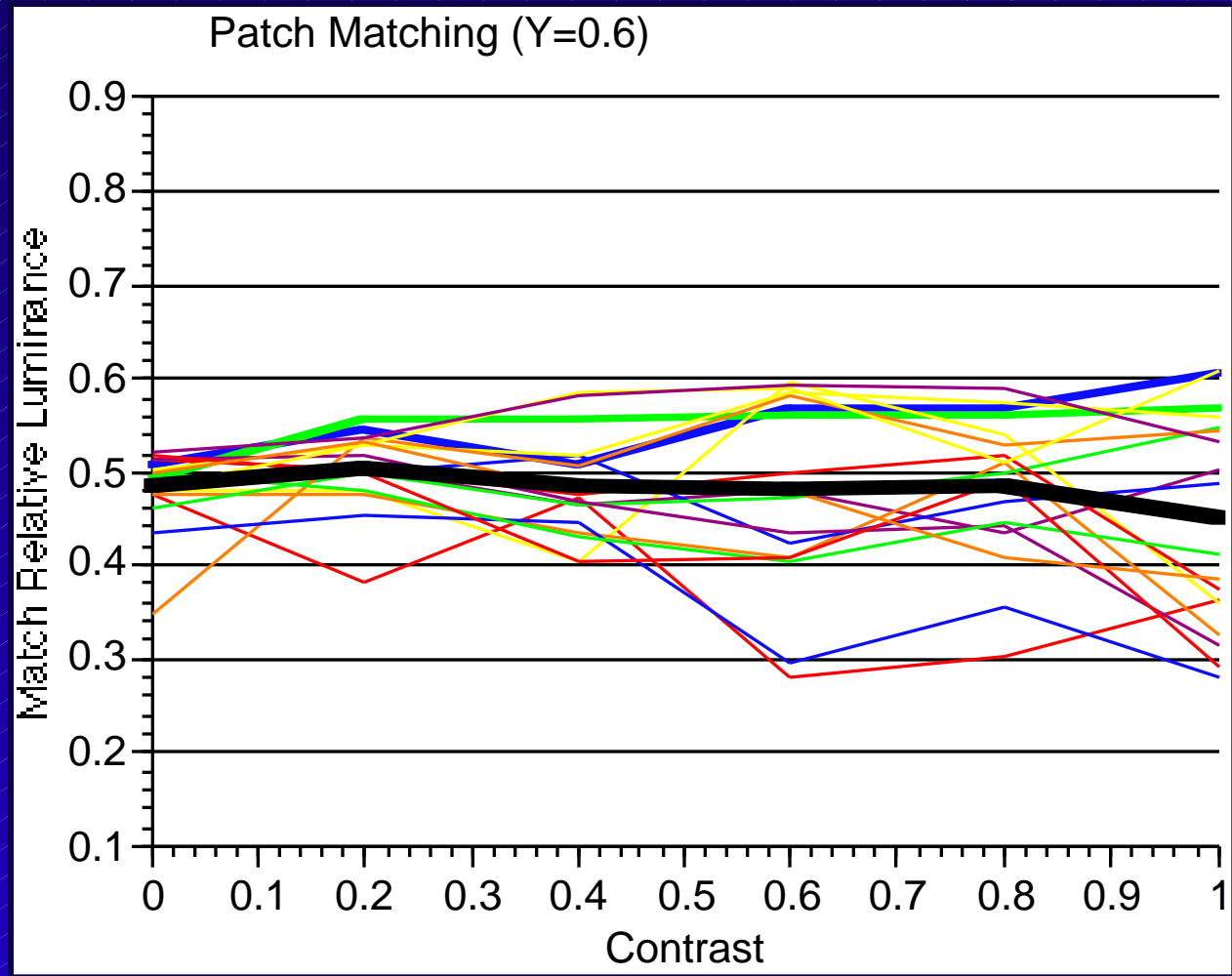
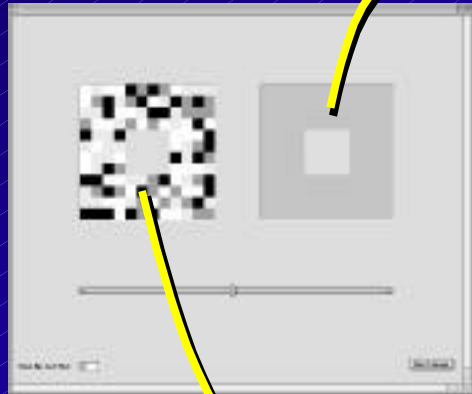


# Results: 0.4 Contrast Matching



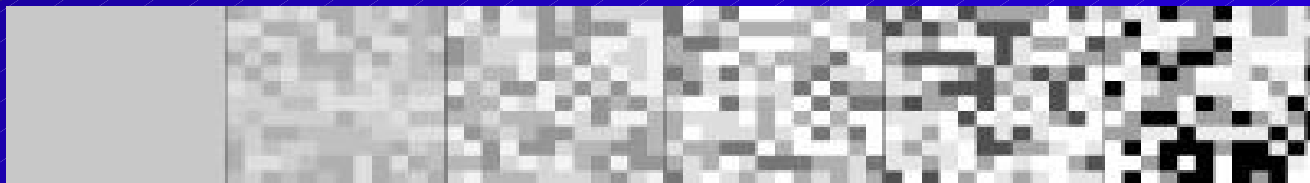
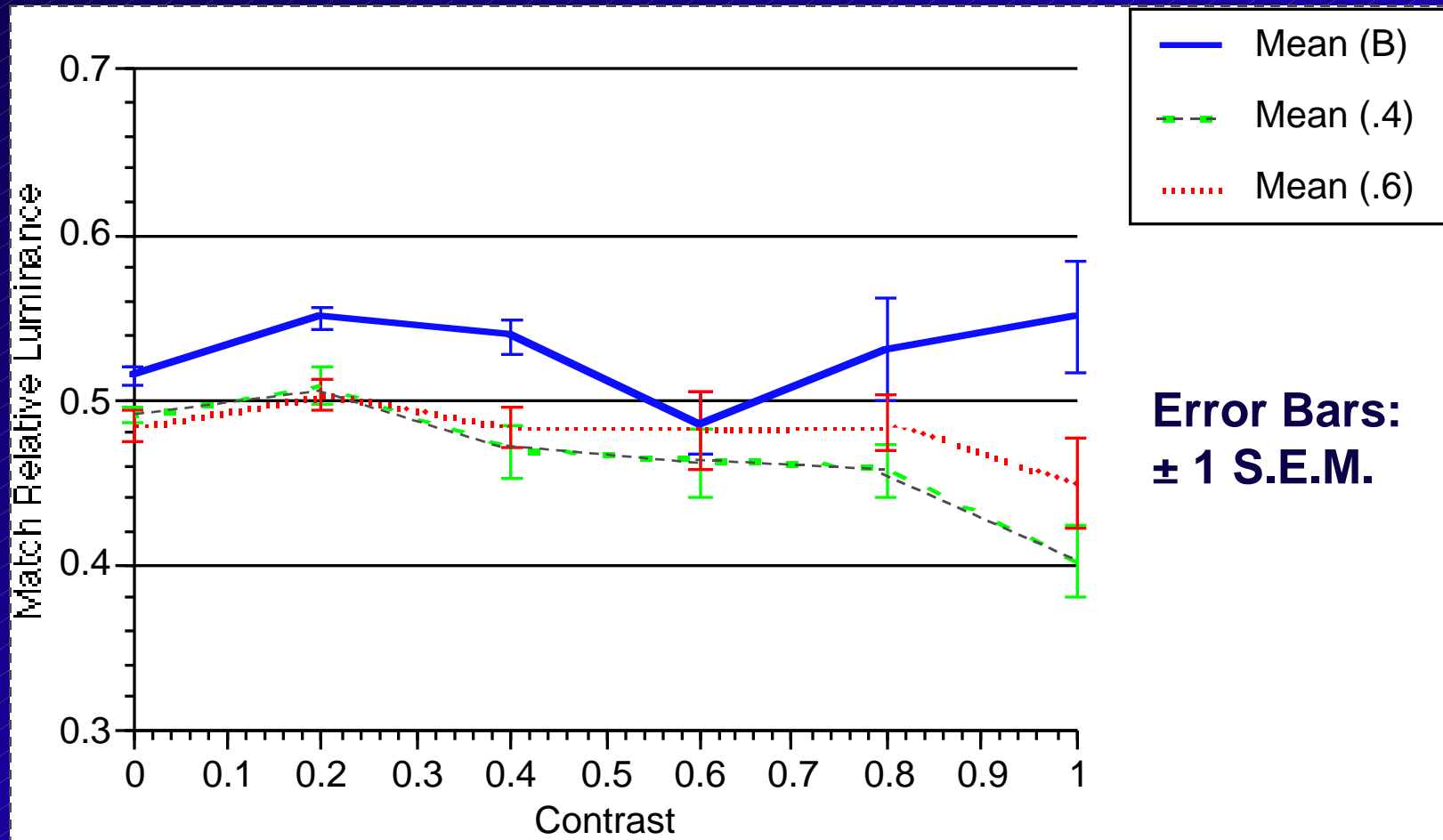


# Results: 0.6 Contrast Matching





# Summary of Results





# Summary Conclusions

- **Image Contrast has Little Effect on Brightness**
- **Very Large Inter-Observer Variability**
- **Quite Small Intra-Observer Variability**

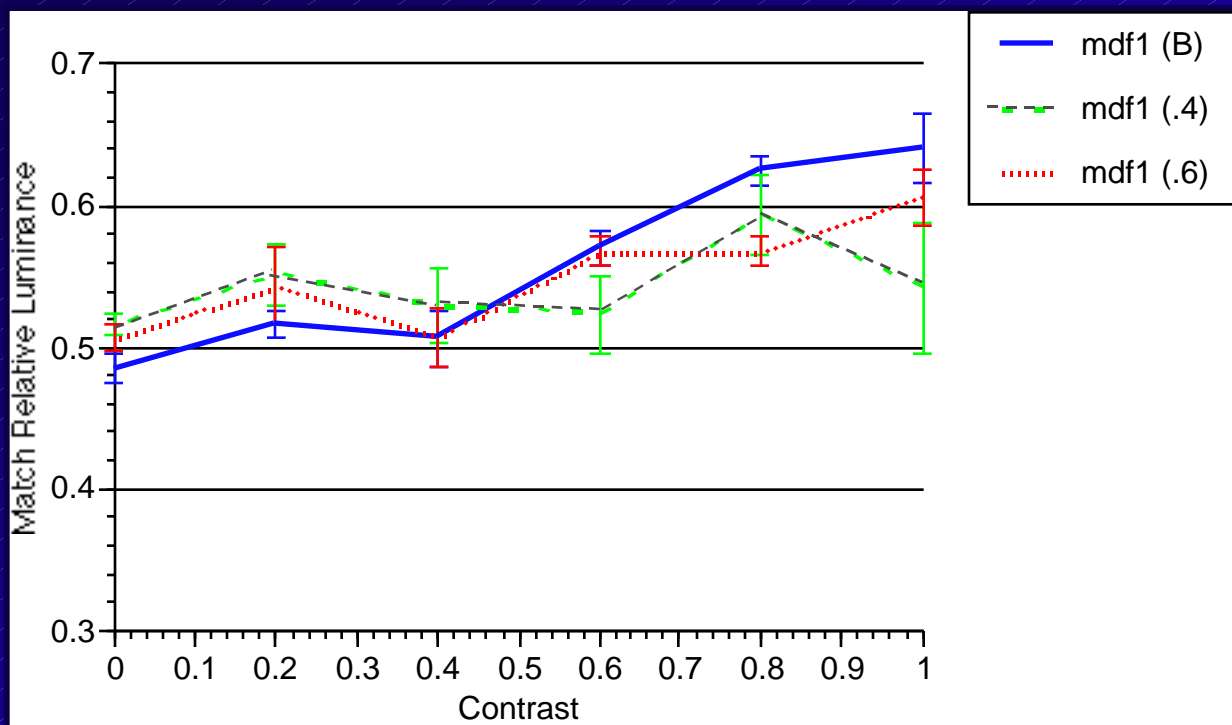
**If Anything:**

- **Slight Trend to Increase Brightness with Contrast (w/dip at 0.6 ... change in mode?)**
- **Slight Trend toward Boost in Lightness of Contrast Patches w/Background Contrast**

***What about those individuals?*** 



# Individual Results: mdf1



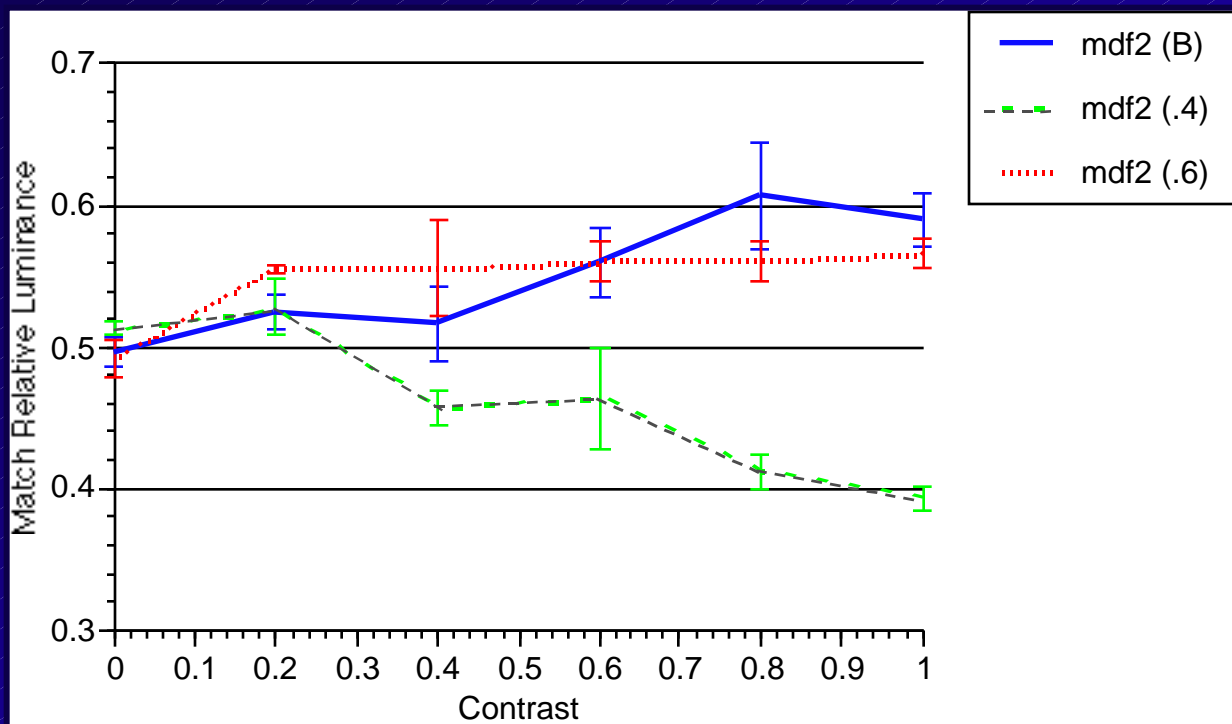
**W/Contrast**

- **Brightness Increases**
- **Simultaneous Contrast Corresponds**
- **Expansive Integration**





# Individual Results: mdf2



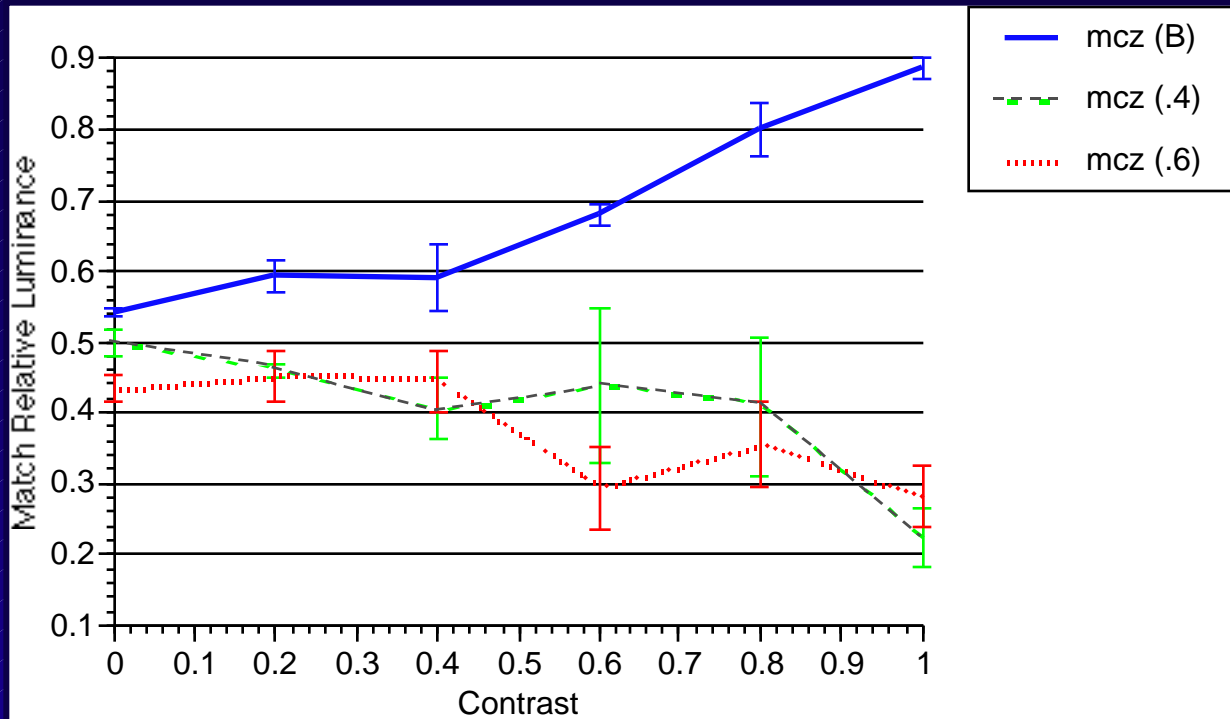
## W/Contrast

- **Brightness Increases**
- **Simultaneous Contrast Decreases**
- **Contrast Gain Control (Zaidi et al.)**

**[New Criterion -> Focus on Patches, Not Background]**



# Individual Results: mcz

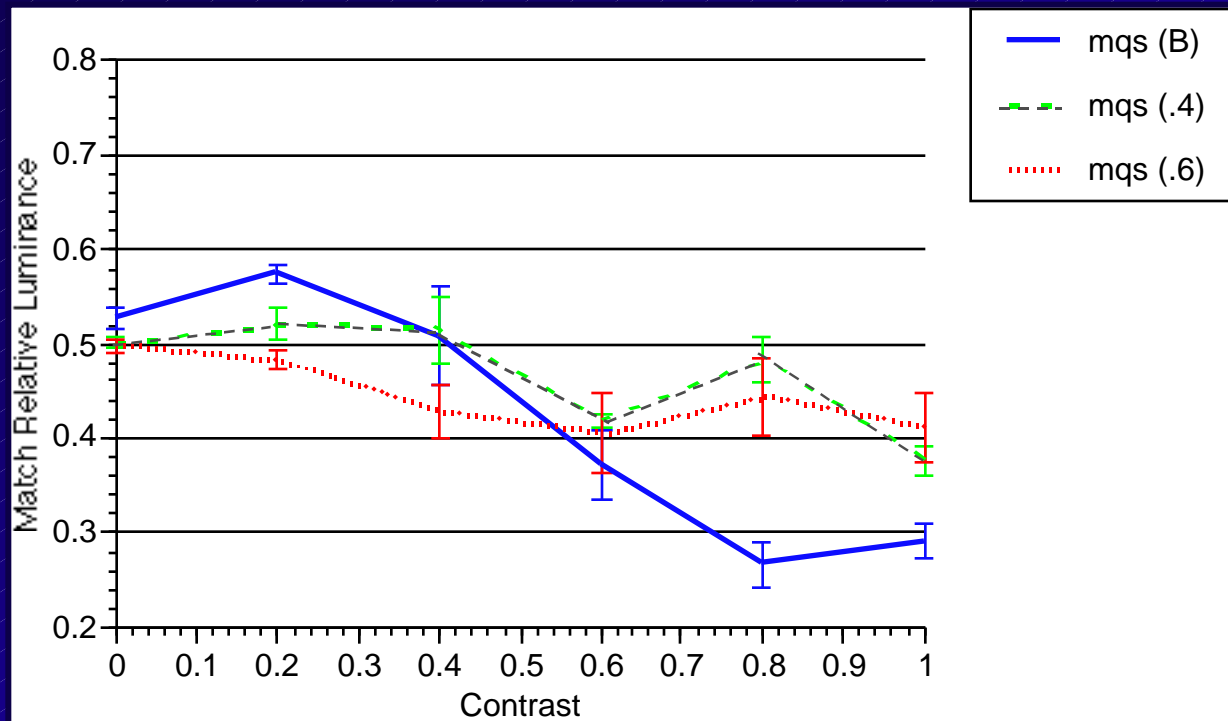


## W/Contrast

- **Brightness Increases**
- **Patches Look Lighter**
- **Clearing Atmosphere (Adelson)**
- **Less Additive Fog**



# Individual Results: mqs

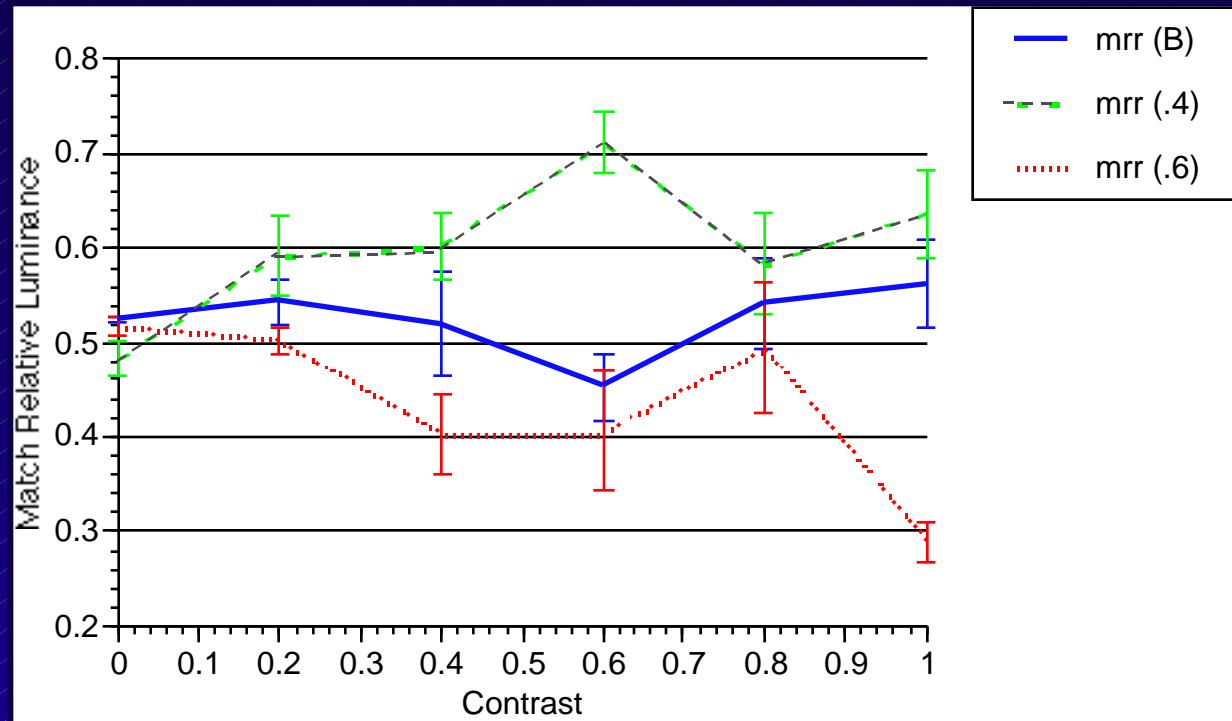


## W/Contrast

- **Brightness Decreases!!**
- **Patches Look Lighter**
- **Consistent Simultaneous Contrast**
- **“Printer”**  
(more black is darker)



# Individual Results: mrr



## W/Contrast

- **Brightness Unchanged (Radiometer)**
- **Simultaneous Contrast Increases**
- **Similar to Schirillo & Shevell**
- **Consistent w/Adelson (more illumination)**



# Conclusions

**Does Brightness Increase with Contrast?**  
*(Original Hypothesis)*

**Sometimes**



# Conclusions

**Is there a Contrast Gain Control?**

*(Zaidi et al., Brown & MacLeod)*

**Sometimes**





# Conclusions

**Is there an Apparent Atmosphere that's  
Discounted?**

*(Adelson)*

**Sometimes**



# Conclusions

**Do We Really Linearly Integrate to Gray?**  
*(Equivalent Background)*

**On Average**



# Conclusions

- **This is why our simple integrating assumptions in color appearance models work well on average & often not well for individuals.**
- **We all bring our cognitive baggage along for these high-level perceptions.**
- **Details of stimulus configuration and task are critical to observed appearance!**
- **Instruction (or context) could make results more consistent.**
- **Carefully interpret experiments with small numbers of observers.**



***Thank You.***

