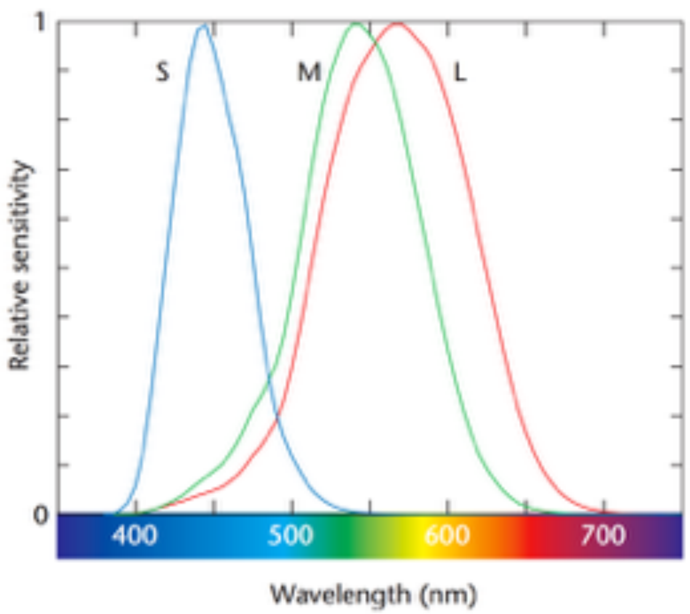
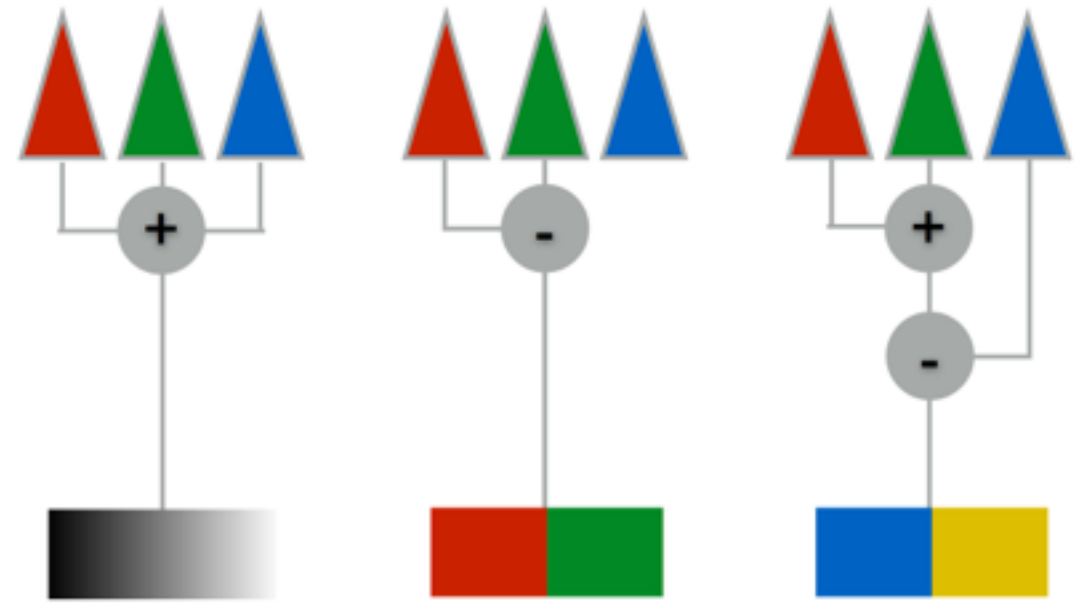
Data Visualization Principles: Color

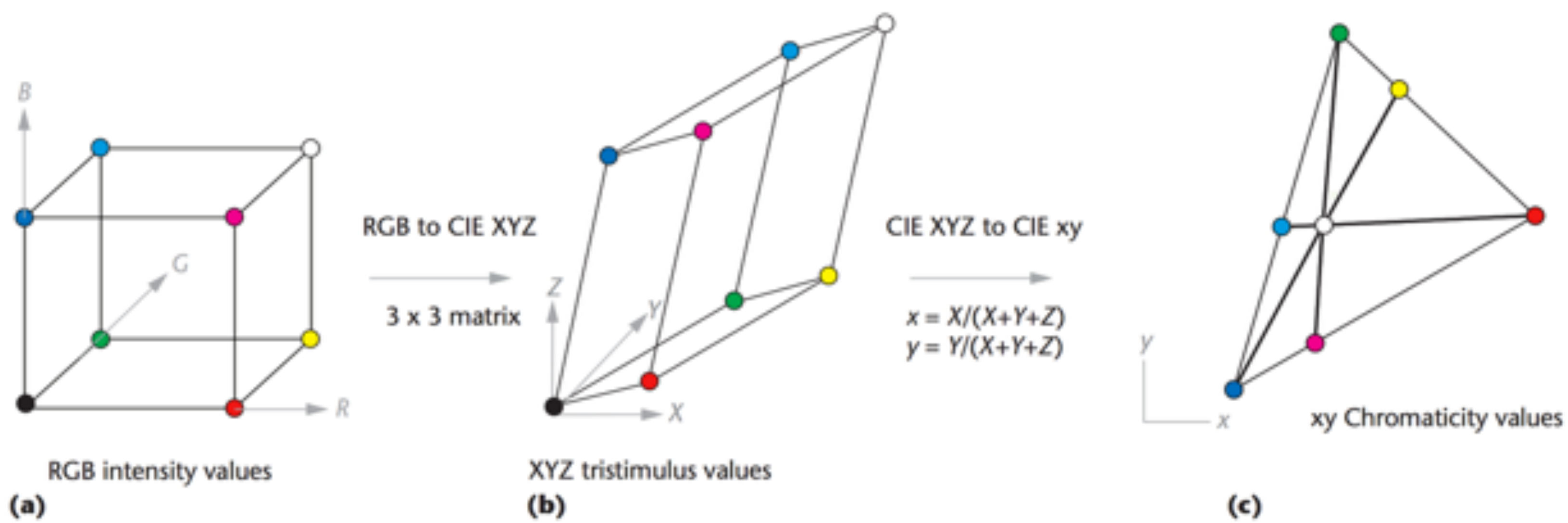
CSC444

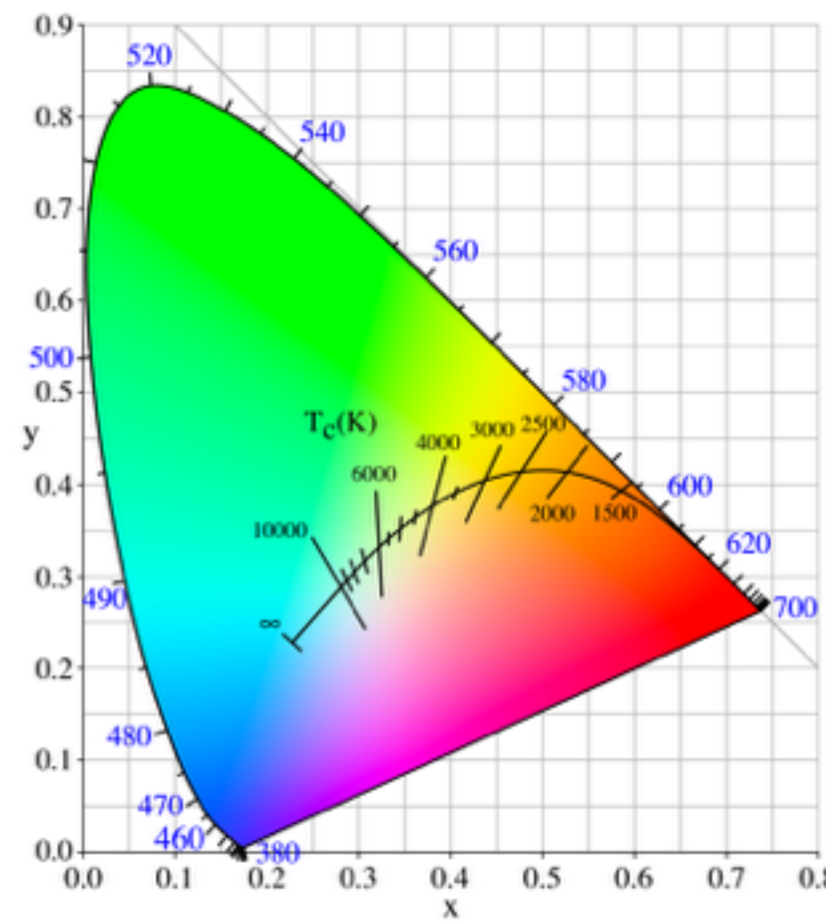
Acknowledgments for today's lecture:
Tamara Munzner, Miriah Meyer, Maureen Stone

RECAP


1
0
S
M
L
Relative sensitivity
400
500
600
700
Wavelength (nm)




B
G
R
RGB intensity values
(a)
RGB to CIE XYZ
3 x 3 matrix
Z
Y
X
XYZ tristimulus values
(b)
CIE XYZ to CIE xy
x = X/(X+Y+Z)
y = Y/(X+Y+Z)
y
x
xy Chromaticity values
(c)

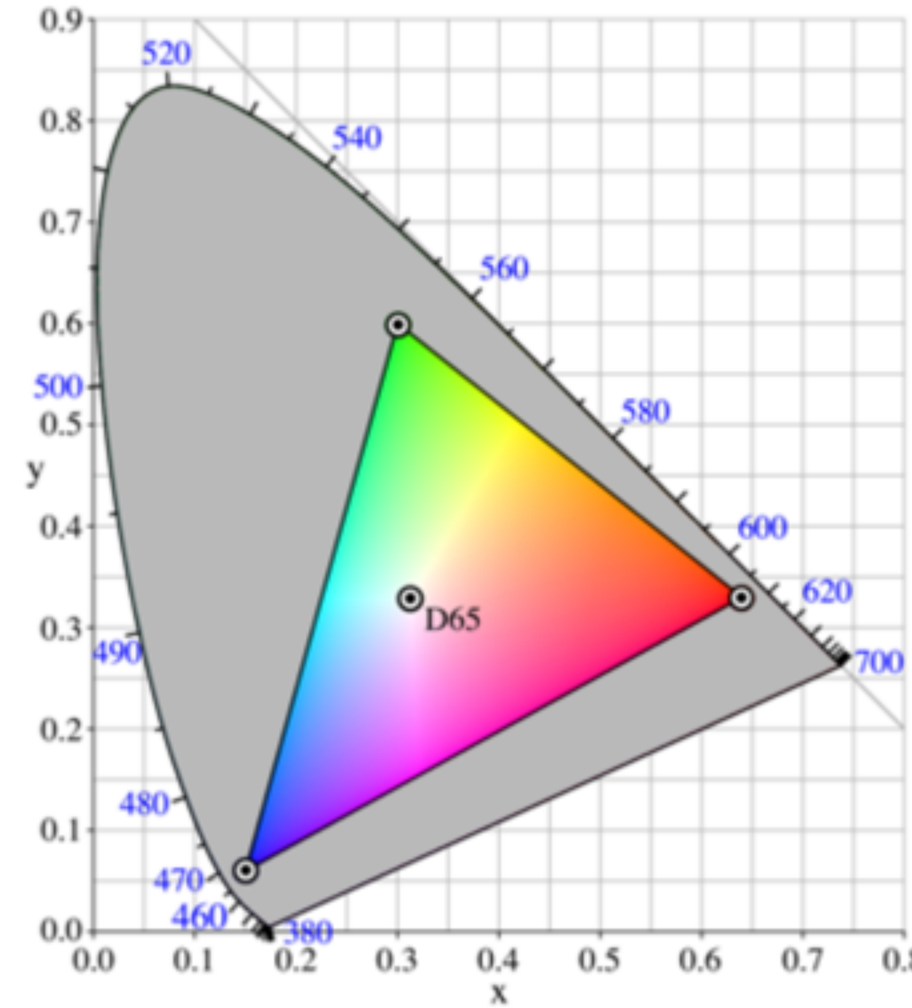

0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
y
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
x
520
540
560
580
600
620
700
500
490
480
470
460
380
Tc(K)
10000
6000
4000
3000
2500
2000
1500
∞

COLOR SPACES

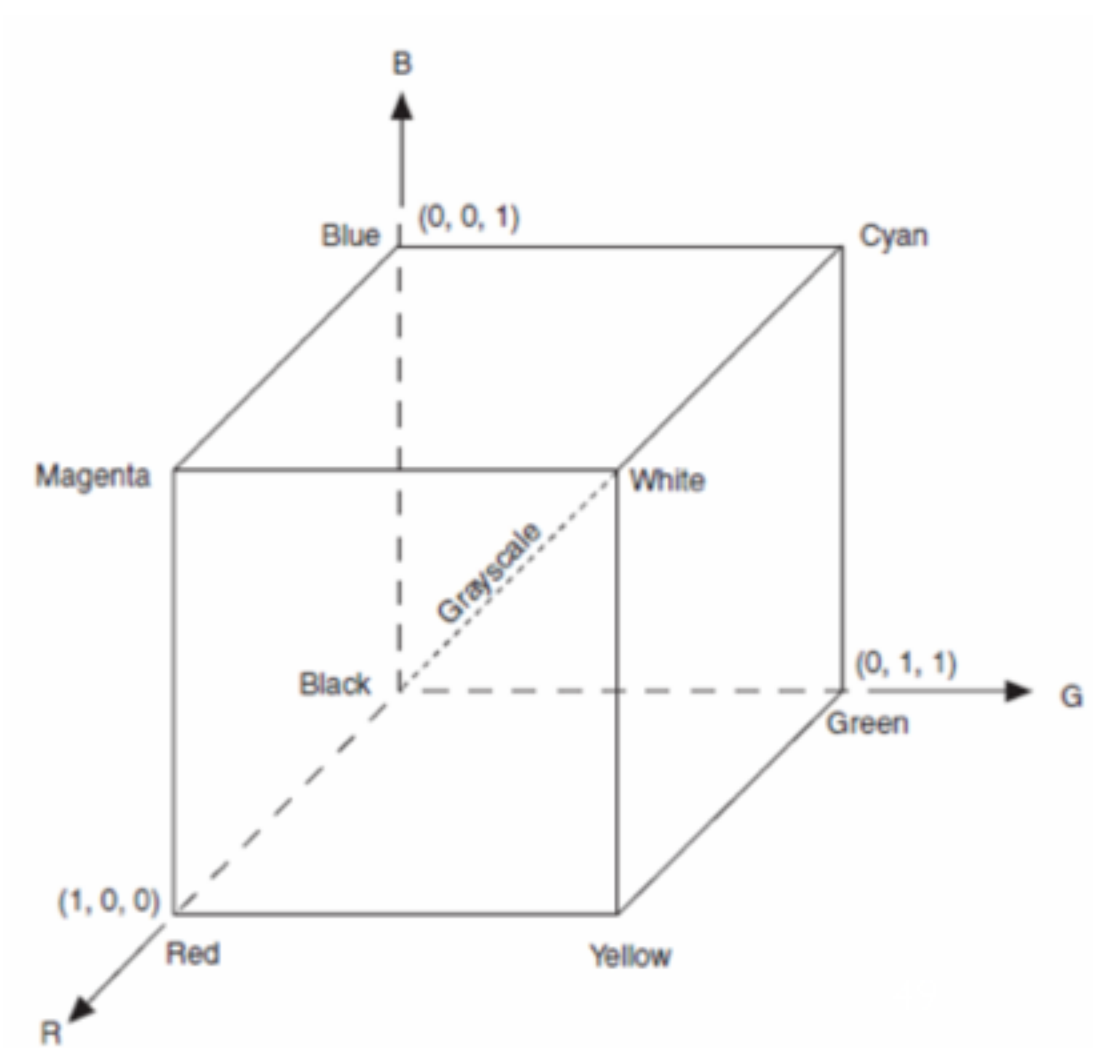
DEVICE DEPENDENT

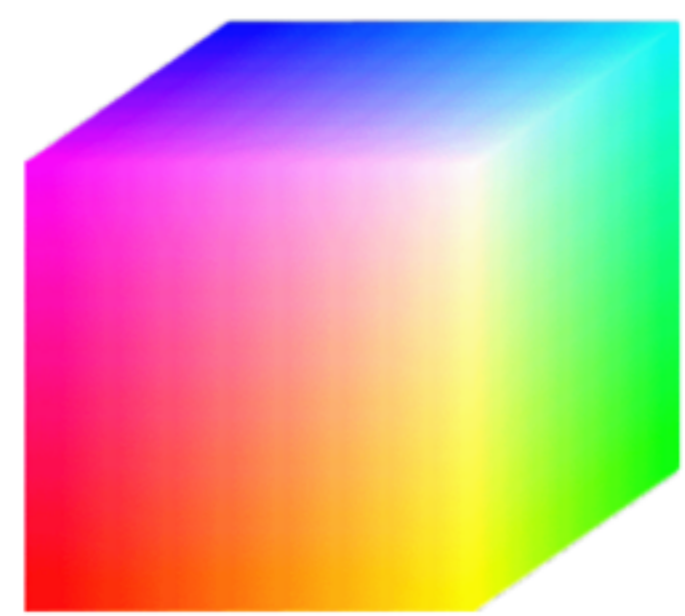
RGB

- Device-centric
- What programs want, **not** what humans want



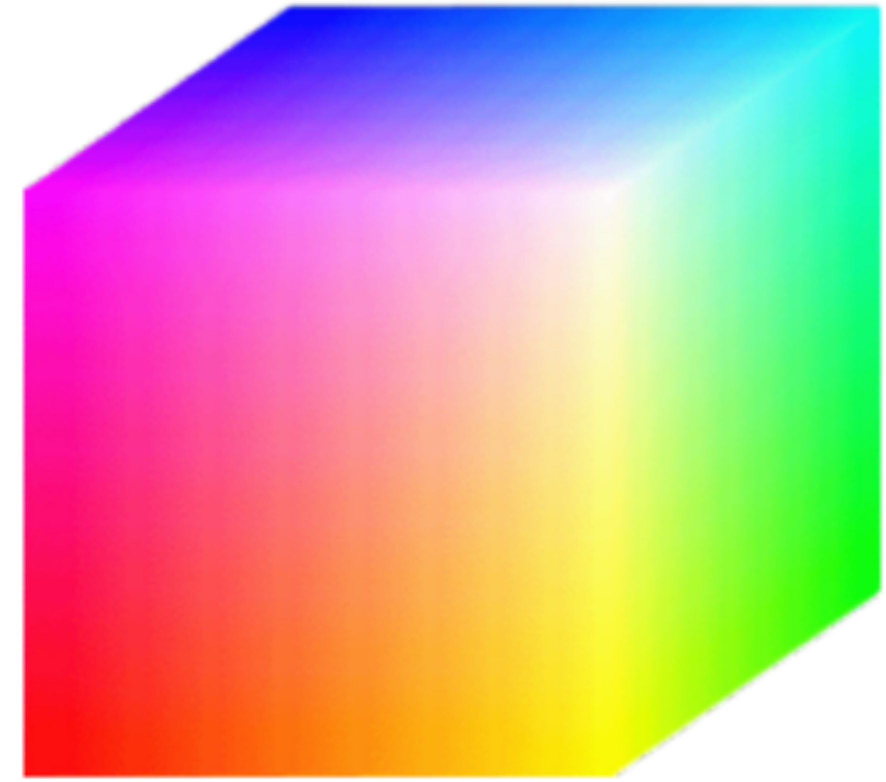
D65: midday sun in Western Europe

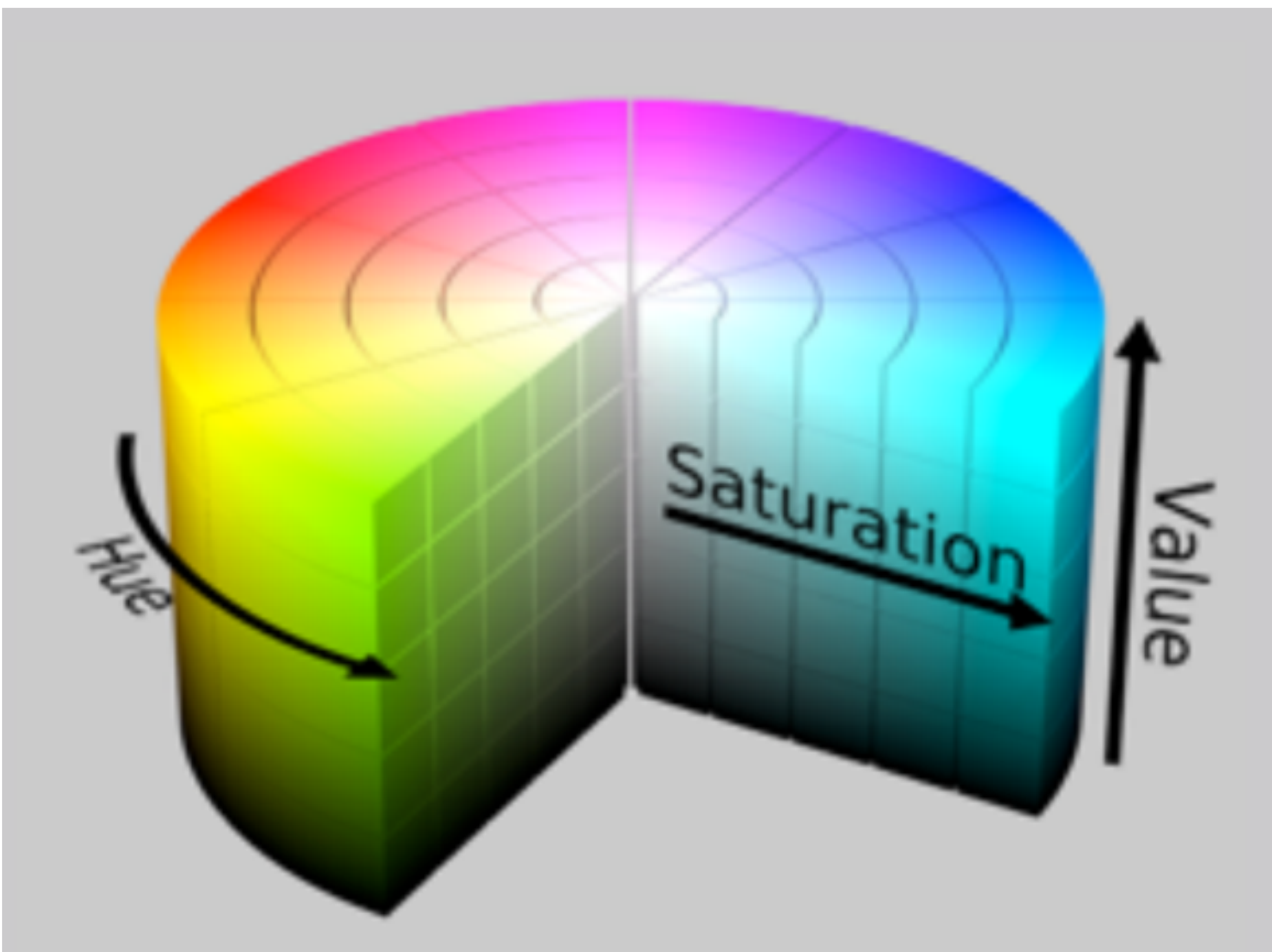




HSV

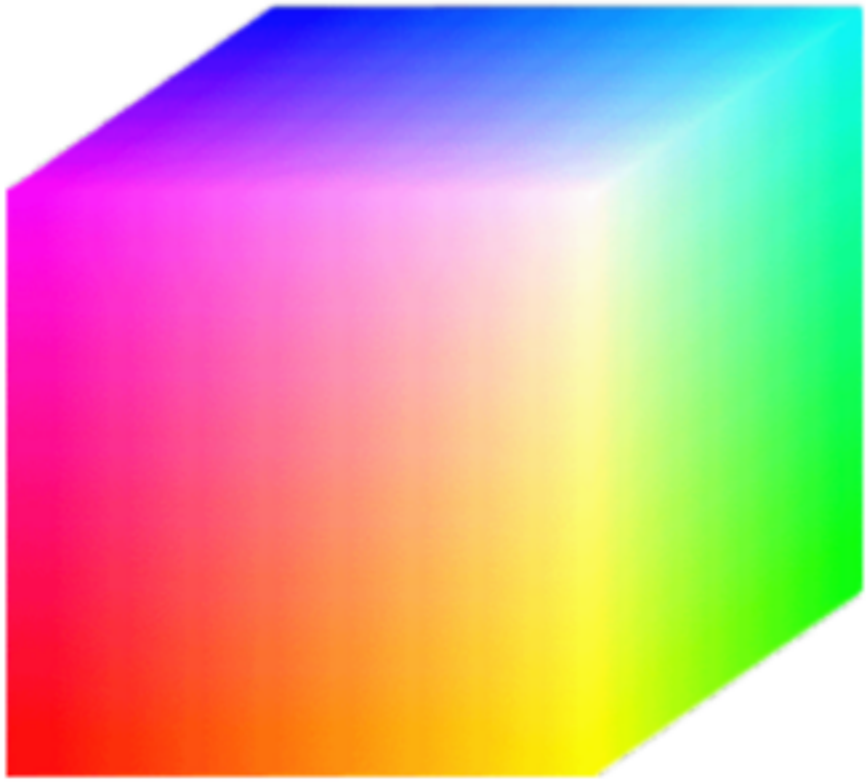
- Still device-centric

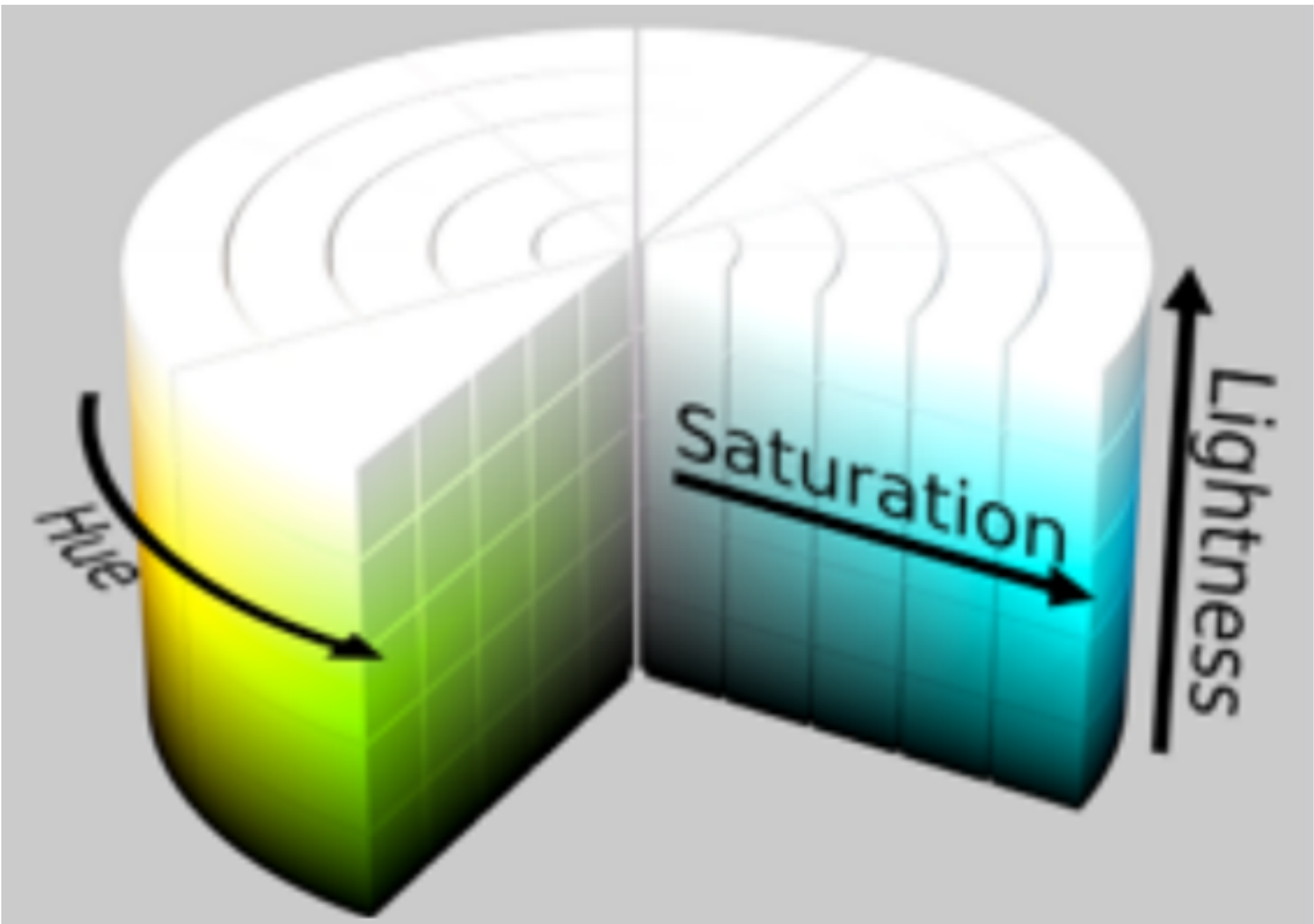




HSL

- Still device-centric

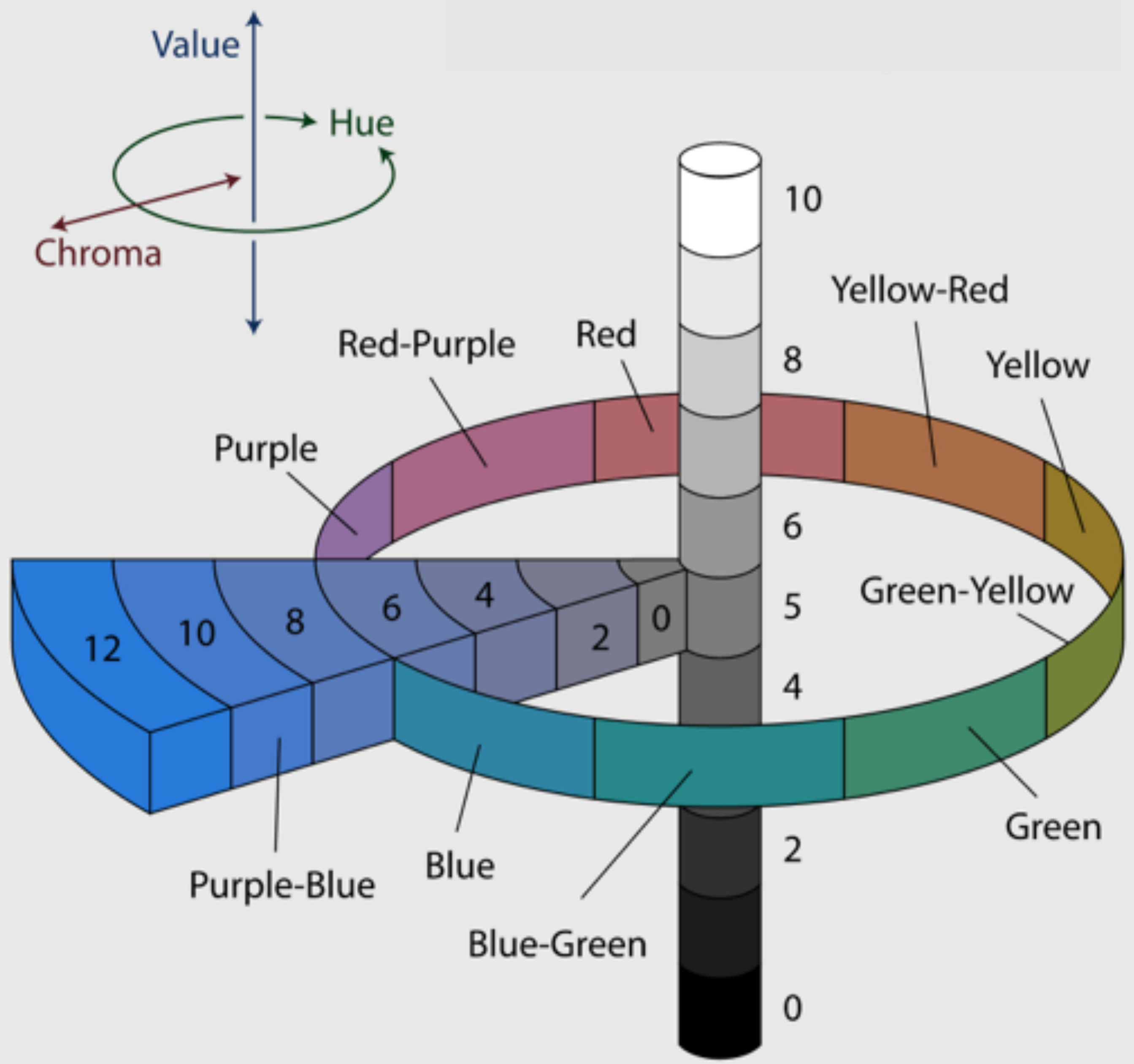




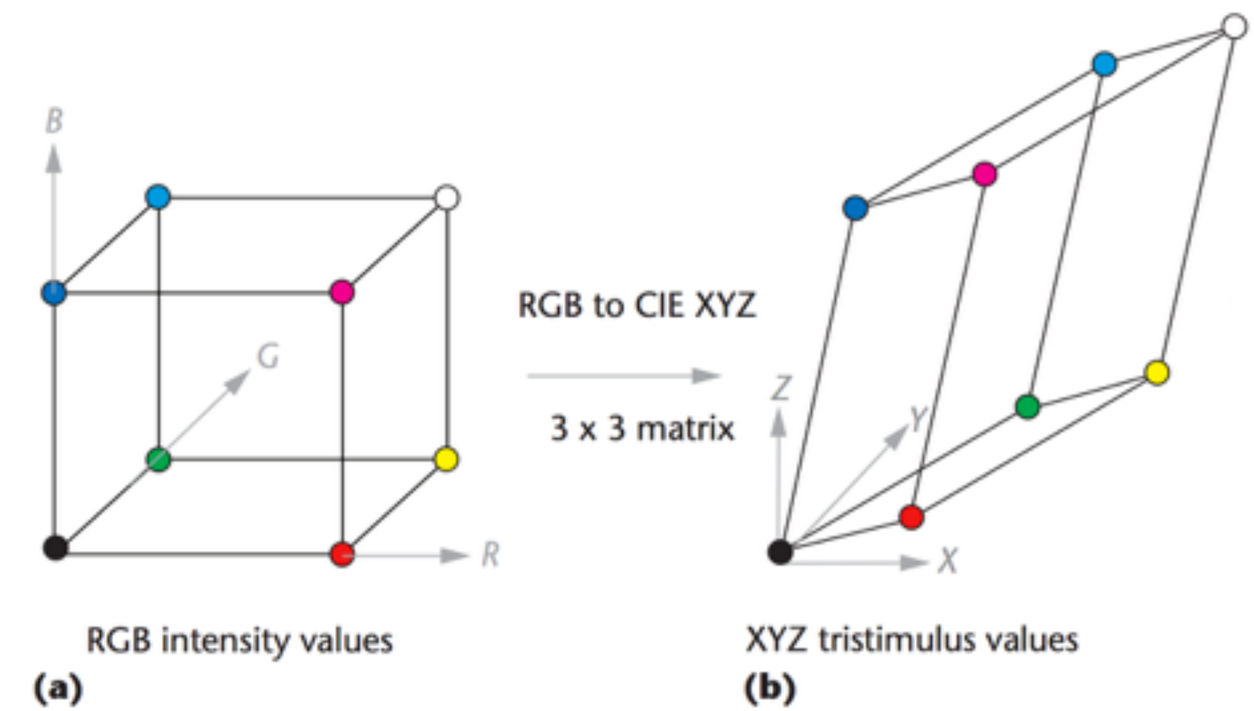
DEVICE INDEPENDENT

Munsell Color System

- **Good**: Perceptually uniform
- **Bad**: Phenomenological, so no physiological or computational basis



XYZ Color Space



- “Optically linear”
- Designed so that all visible colors have positive coordinates, and Y is “luminance”

LUV Color Space

- “Perceptually uniform”
  - Euclidean distance corresponds to perceptual distance (**very useful!**)

Polar LUV (or HCL)

- “Perceptually uniform”, like LUV
- Transform UV to polar coordinates: radius is Chroma, Angle is Hue
- Conversion to/from RGB is complicated, but distances in HCL make sense, **and** it makes sense for humans
    - **Like HSV, but good. All else being equal, think HCL first**

Demos

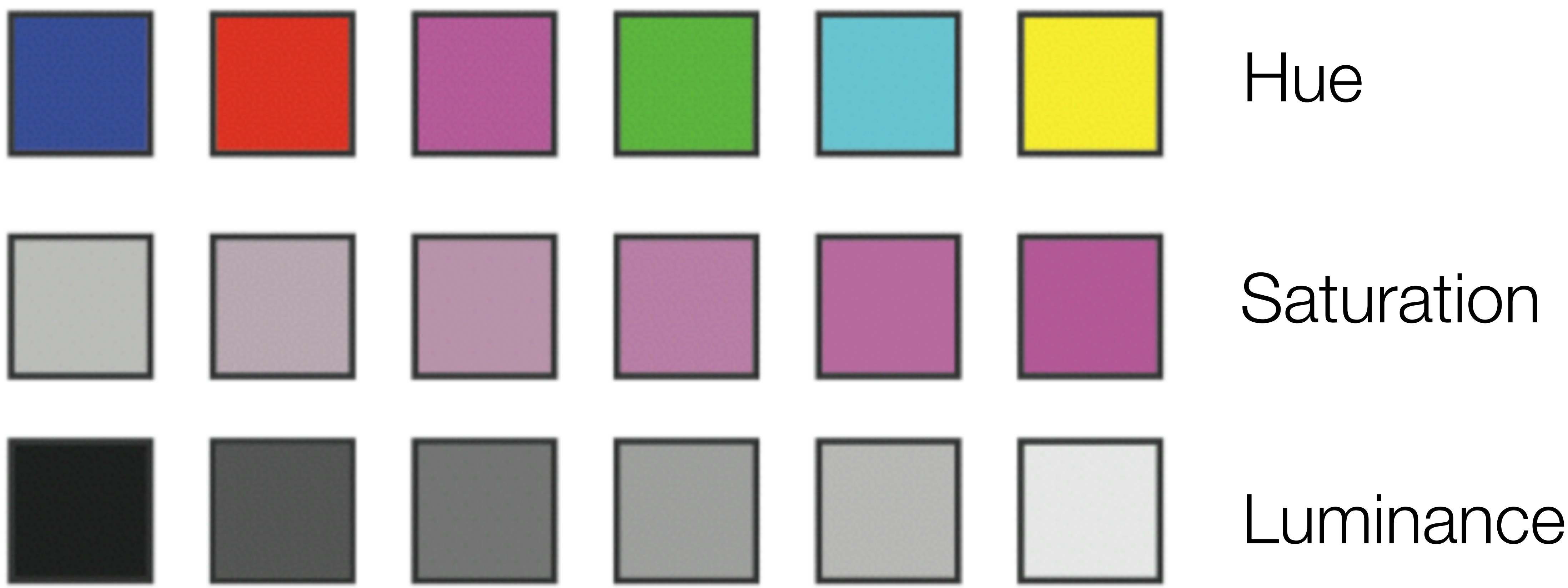
http://cscheid.net/static/20120216/hsv_frame.html

http://cscheid.net/static/20120216/xyz_frame.html

http://cscheid.net/static/20120216/luv_frame.html

http://cscheid.net/static/20120216/hcl_frame.html

Let’s use consistent names in class

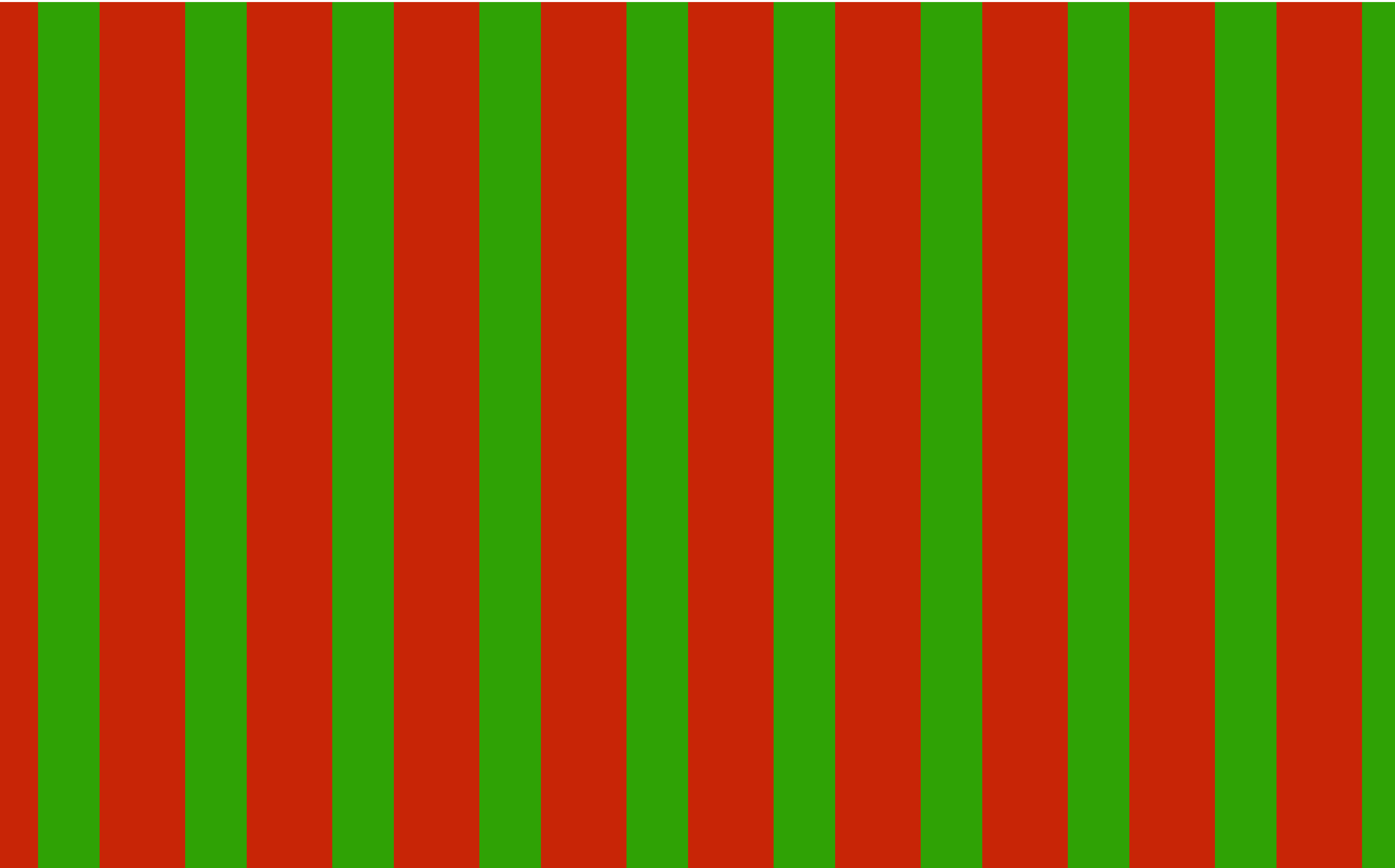


CONSEQUENCES FOR DESIGN

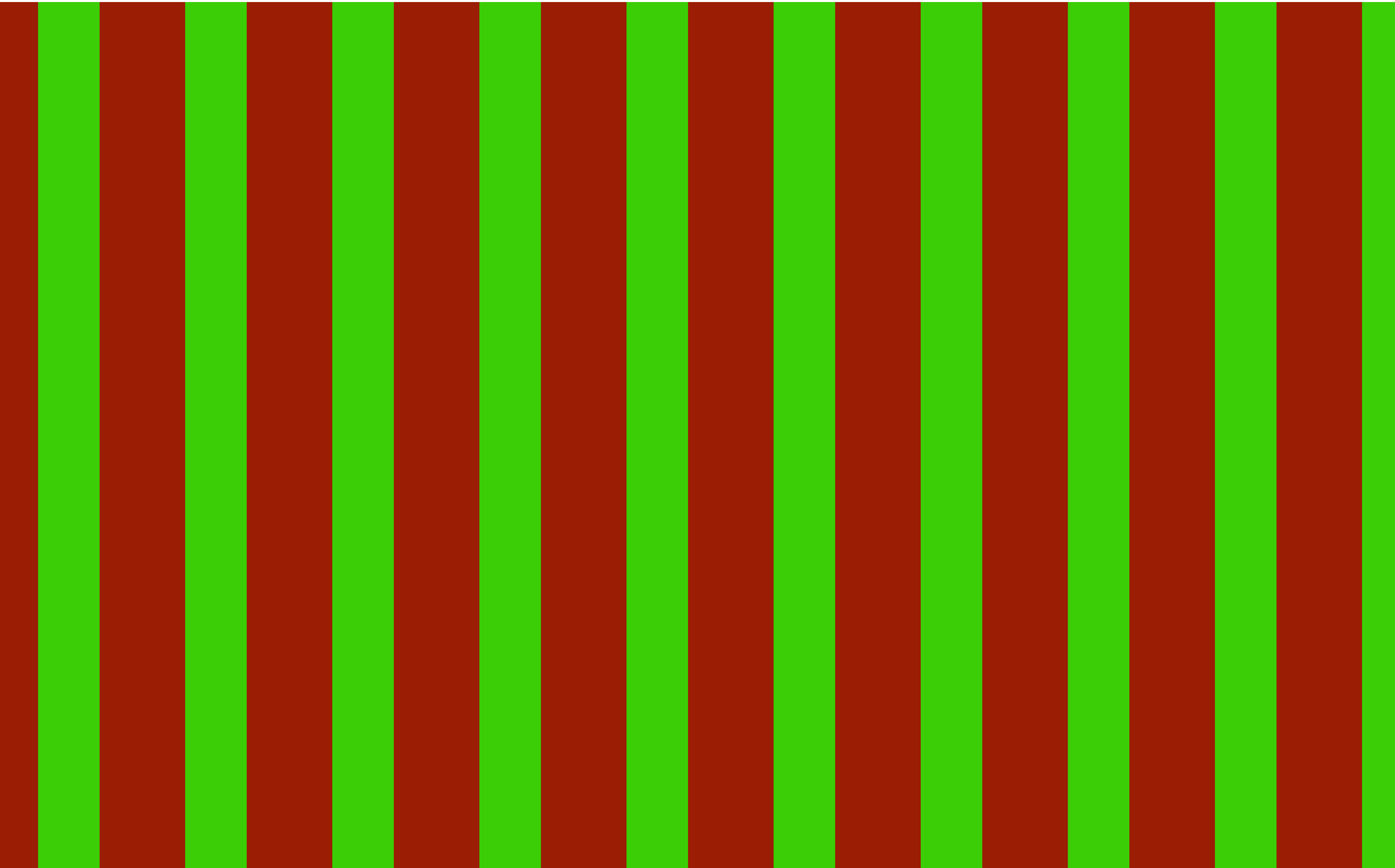
“Get it right in black and white”

–Maureen Stone

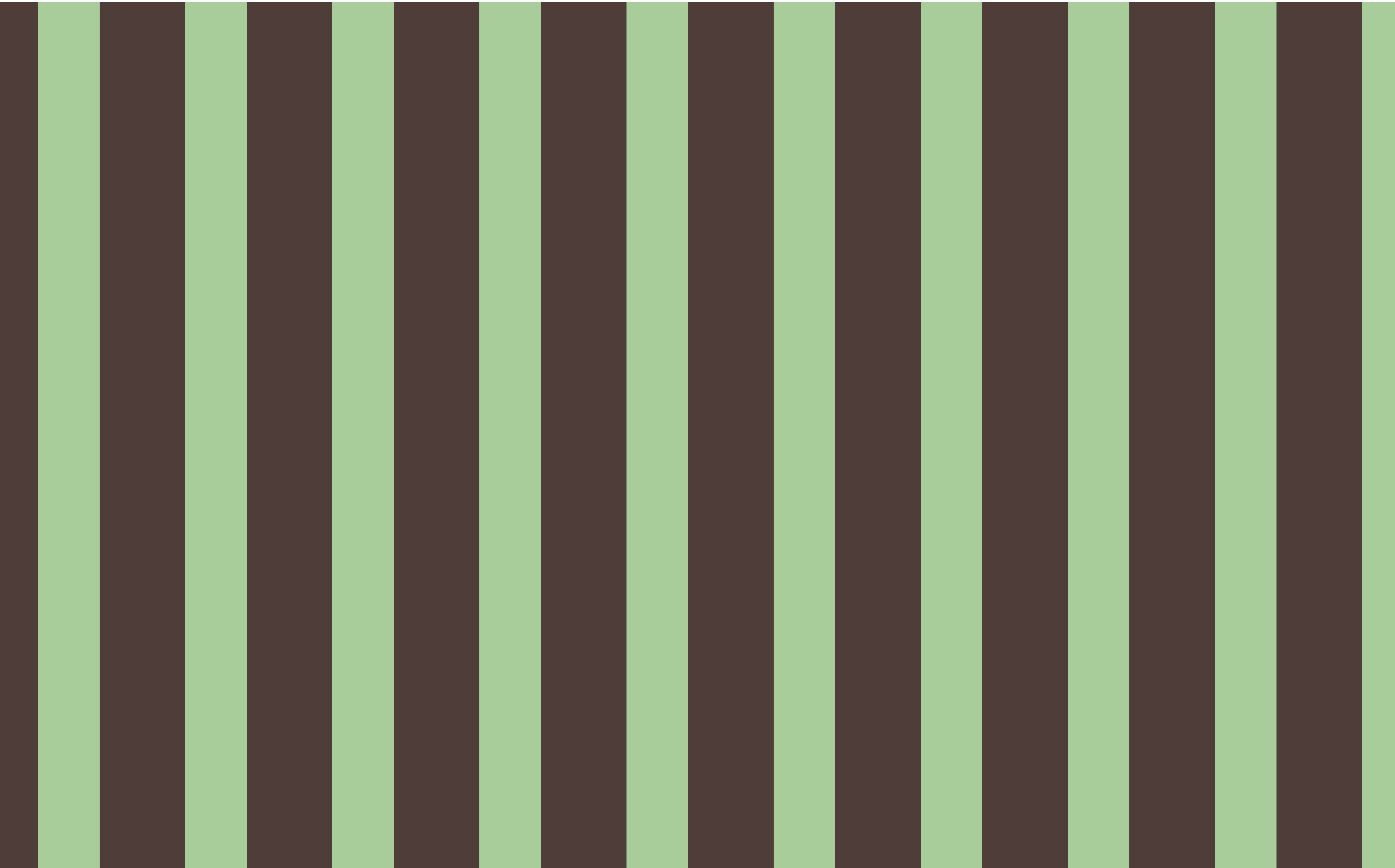
If you’re going to show shape variation, do it with luminance

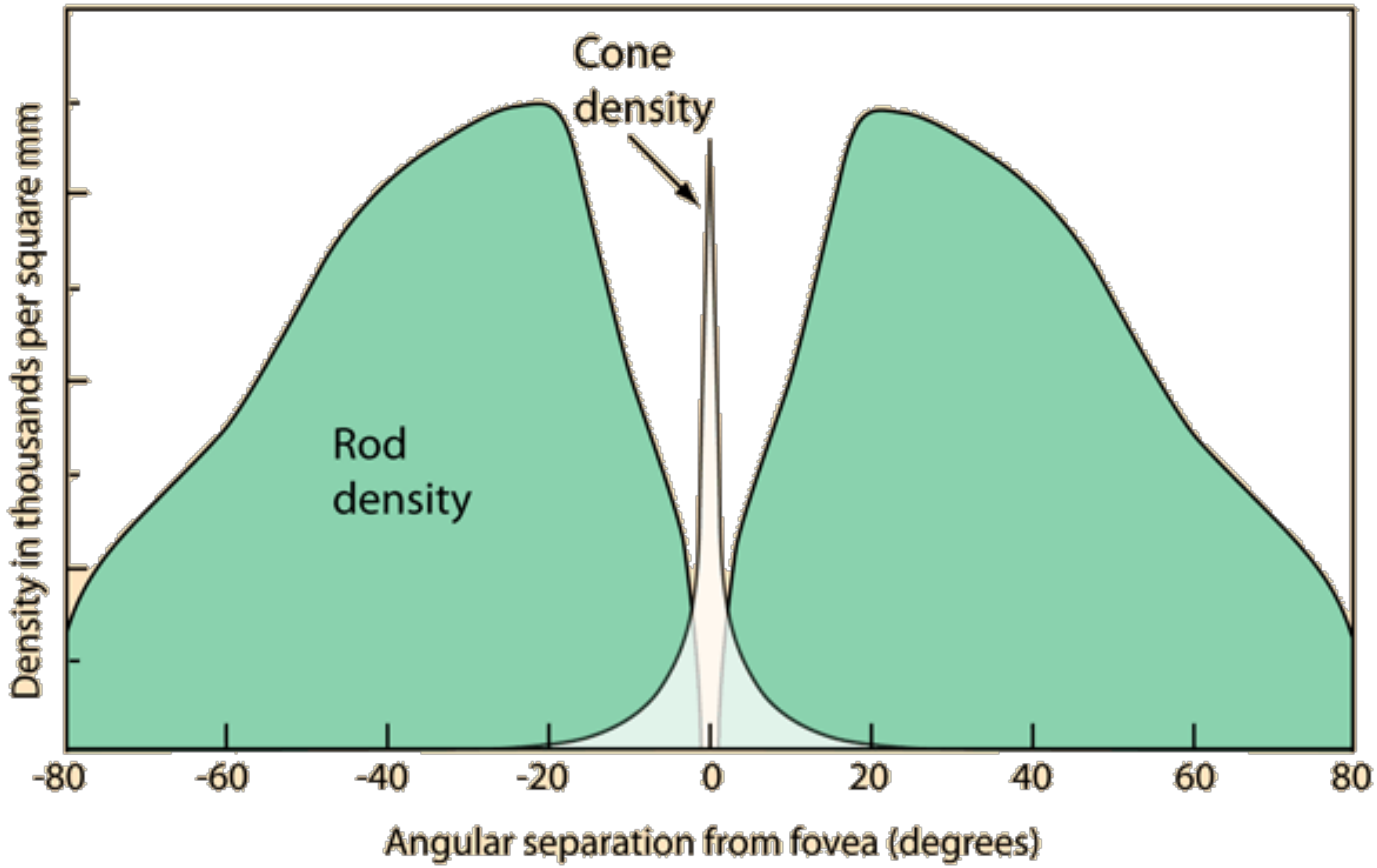


If you’re going to show shape variation, do it with luminance

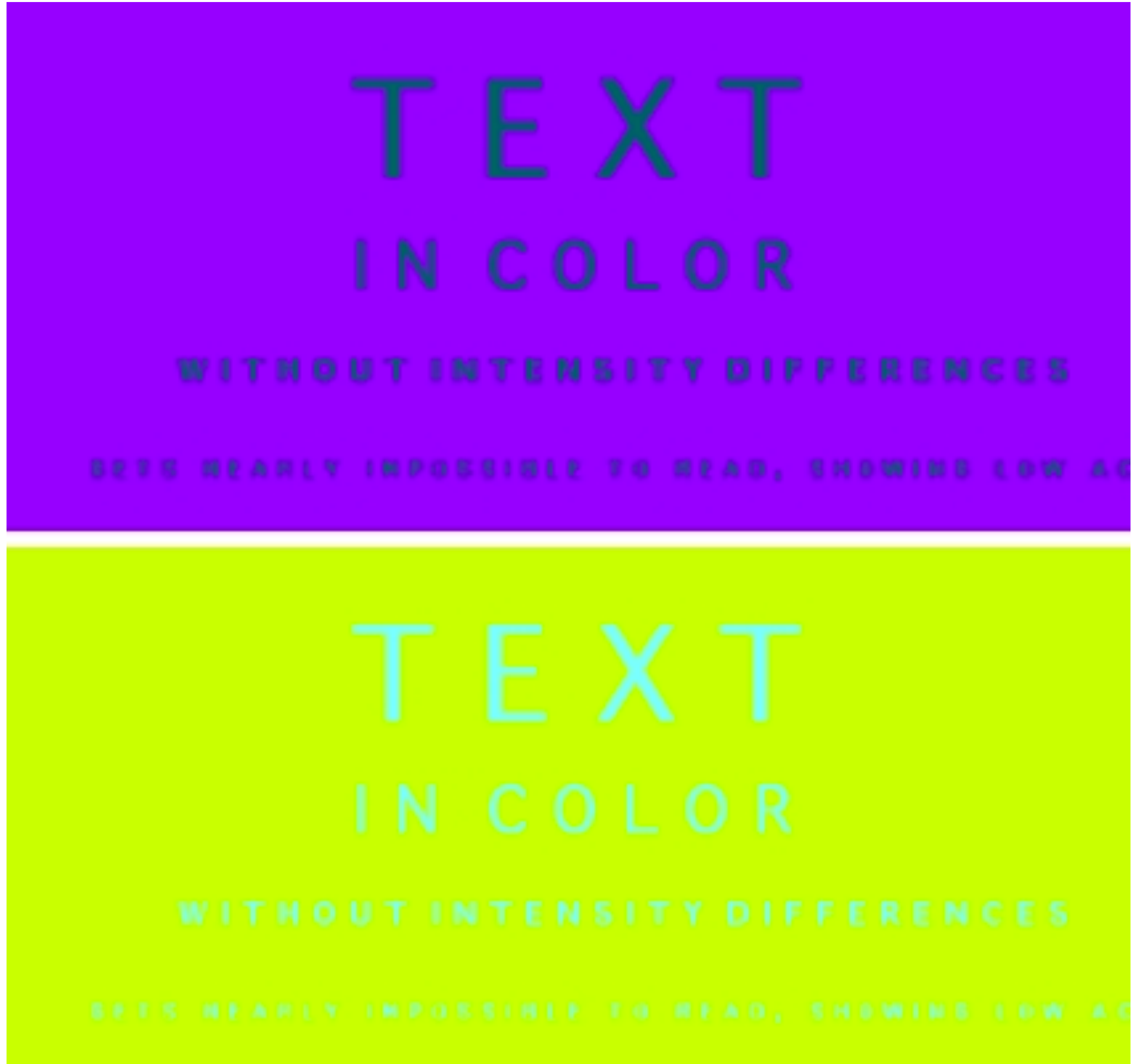


If you’re going to show shape variation, do it with luminance





(You can see stars better by looking away from them!)

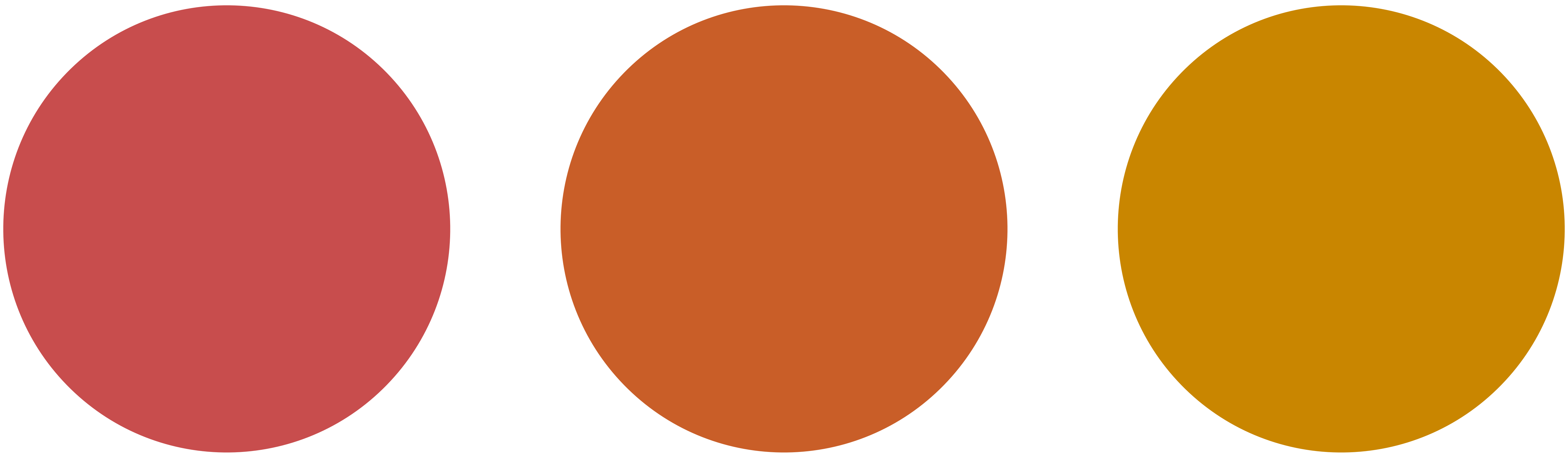


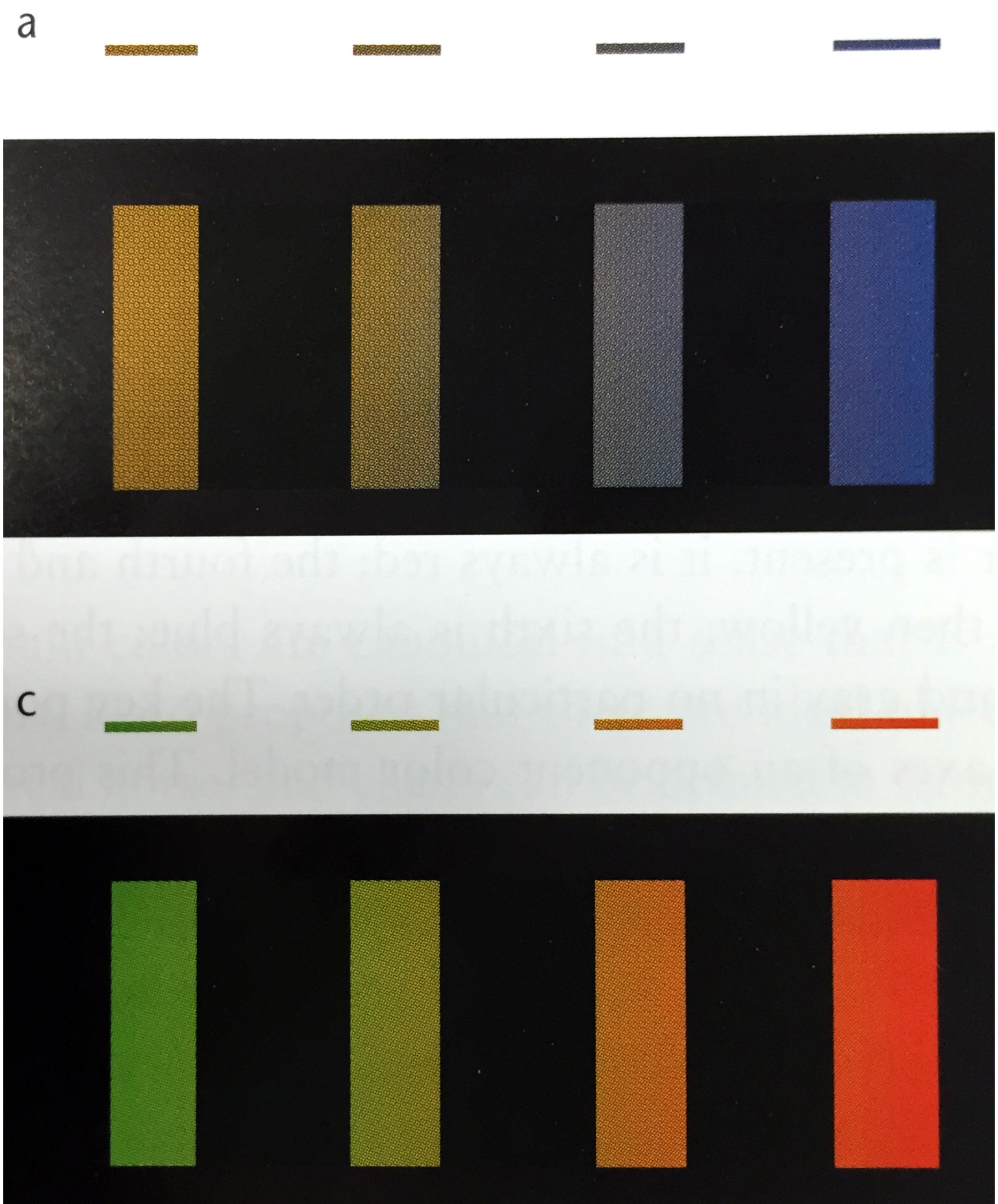
http://www.settheory.com/Glass_paper/color_motion.gif

http://www.settheory.com/Glass_paper/Kanizsa_observations.html

Do not rely only on hue boundaries to depict shape

Do not rely only on hue boundaries to depict shape





Ware, Chapter 4

Area affects saturation perception

A Color-Caused Optical Illusion on a Statistical Graph

WILLIAM S. CLEVELAND and ROBERT McGILL*

Despite the great increase in the use of color in statistical graphics, we know very little about how color affects people's perception of the quantitative information on graphical displays. Perceptual psychologists have already demonstrated that color can cause optical illusions of various kinds. We ran a simple experiment to see if this can happen with a statistical map and found that an illusion did occur.

KEY WORDS: Statistical map; Psychophysics; Bootstrap; Computer graphics; Barycentric plot.

1. INTRODUCTION

Color is being used more and more in statistical graphics. The availability of color output devices for computers has greatly increased, and with easy access to these devices has come an enormous increase in the use of color graphics in the mass media, business reports, and government publications.

Scientific journals are turning to color. In the 10 April 1981 issue of *Science*, for example, substantial use is made of color: a graphical display in which two sets of data are distinguished by plotting one in black and one

areas on each map, and the experimental data were used to determine whether some colors caused areas to look bigger than others. This article describes the experiment and the results of the data analysis.

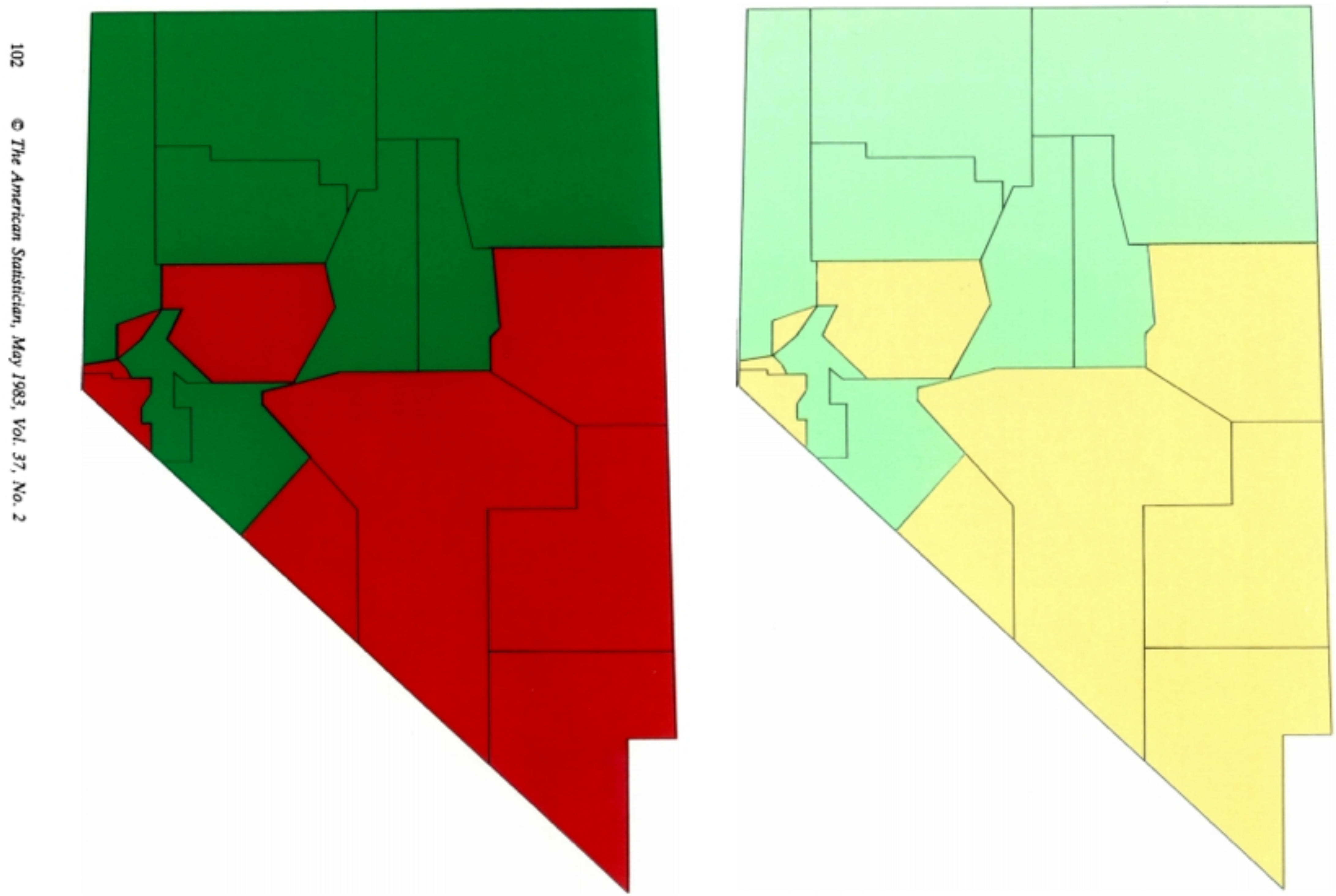
2. EXPERIMENTAL STIMULI AND PROCEDURES

The basic stimulus was a map of Nevada with county boundaries. The geometry of this map is not overly complex—most boundaries are essentially straight lines—yet the sizes and configurations of the counties are not sufficiently regular that estimates of areas could be made by counting them, as might be done on a map of Kansas or Iowa. The number of counties, 17, allows reasonably easy judgment. In no case was a subject required to mentally sum more than 10 areas.

Each stimulus in the experiment was a two-color map with the total area of the counties that were coded by one color very nearly equal to the total area of those that were coded by the second color. One stimulus is shown in Figure 1. There were 10 such divisions of counties into two groups, and in no case did the difference of the areas exceed two square miles.

From the 10 divisions of counties into two groups, four sets of stimuli were generated, each set with the 10 maps previously described. In the first set one group of

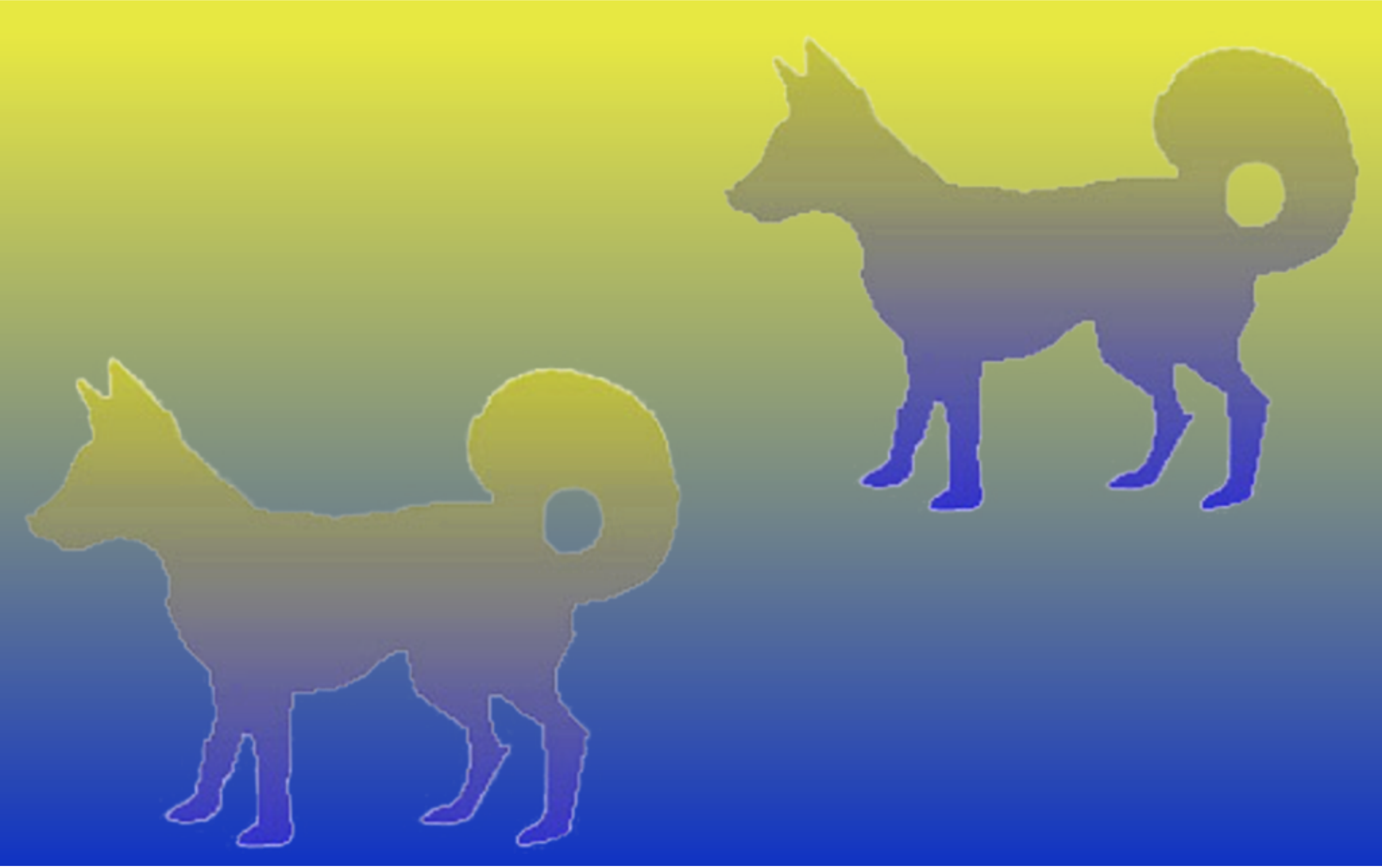
Saturation affects area perception

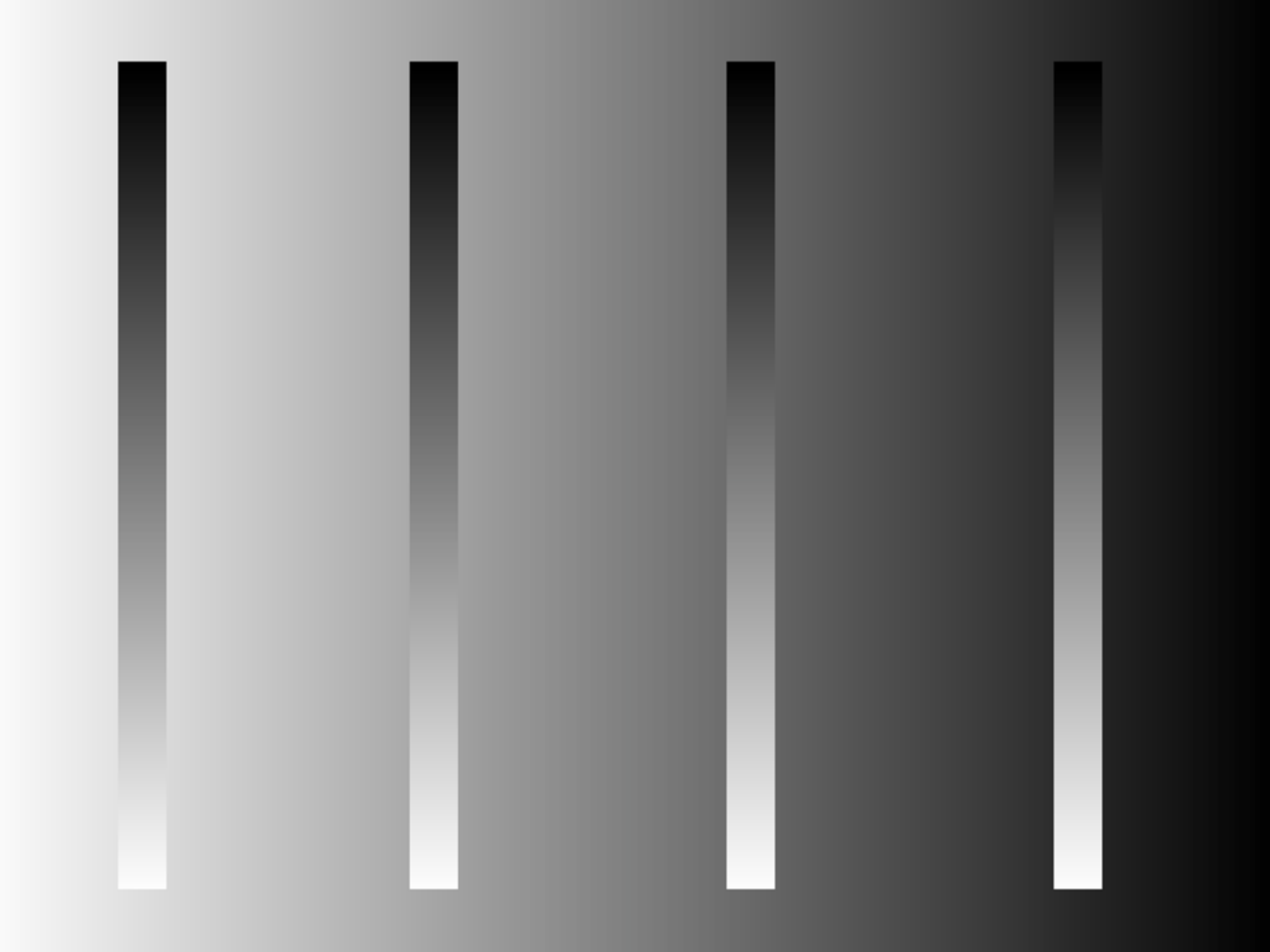


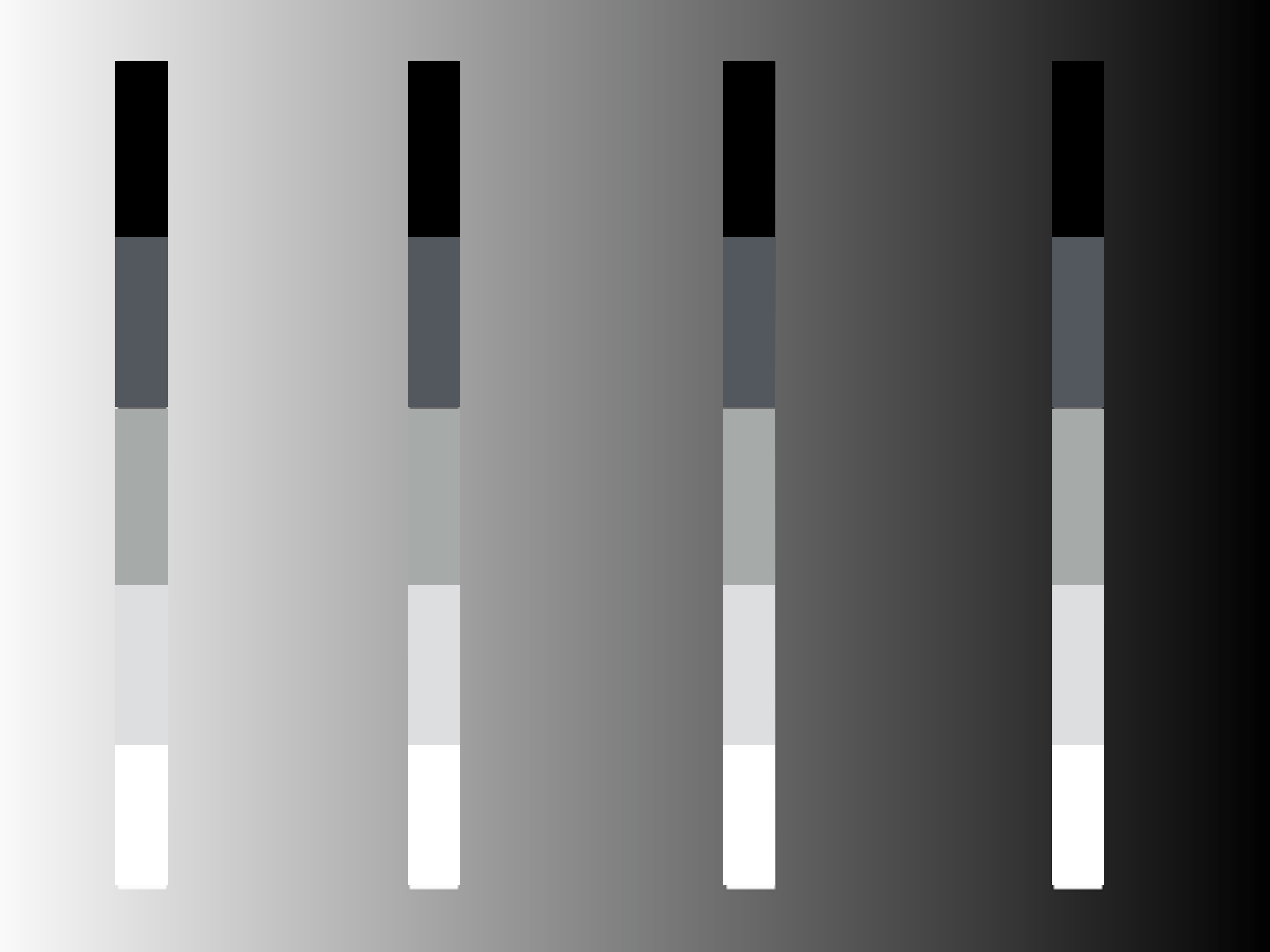
Area affects saturation perception

Saturation affects area perception

Imagine the mess if you try to use both…







Simultaneous contrast is a problem

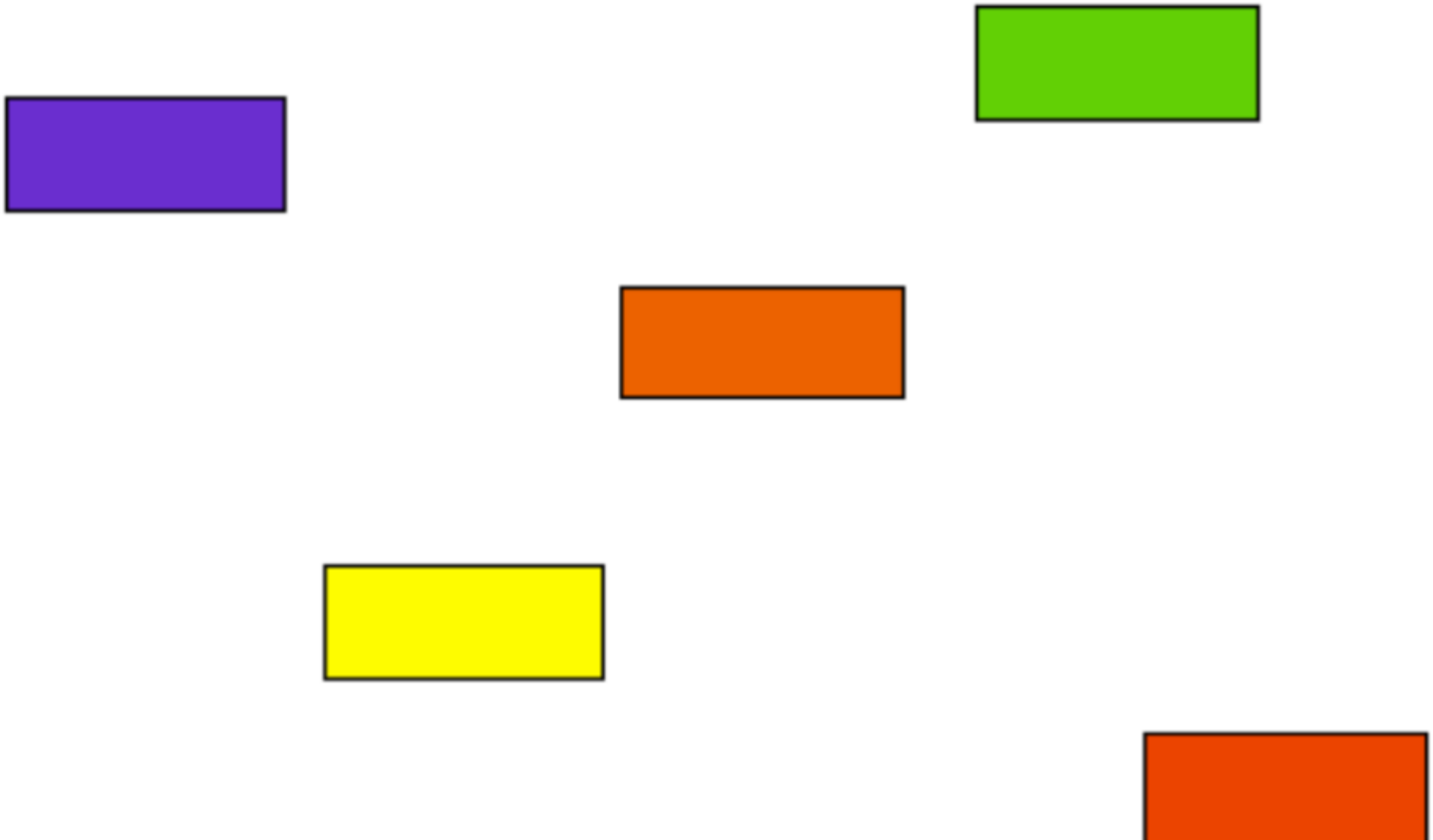
Quantize the plot if background is non-constant
(This comes at a fidelity cost for the data)

“Categorical” data

- Sometimes there’s no implied relationship between different levels of a variable
  - Stimuli must look different, but **only** different

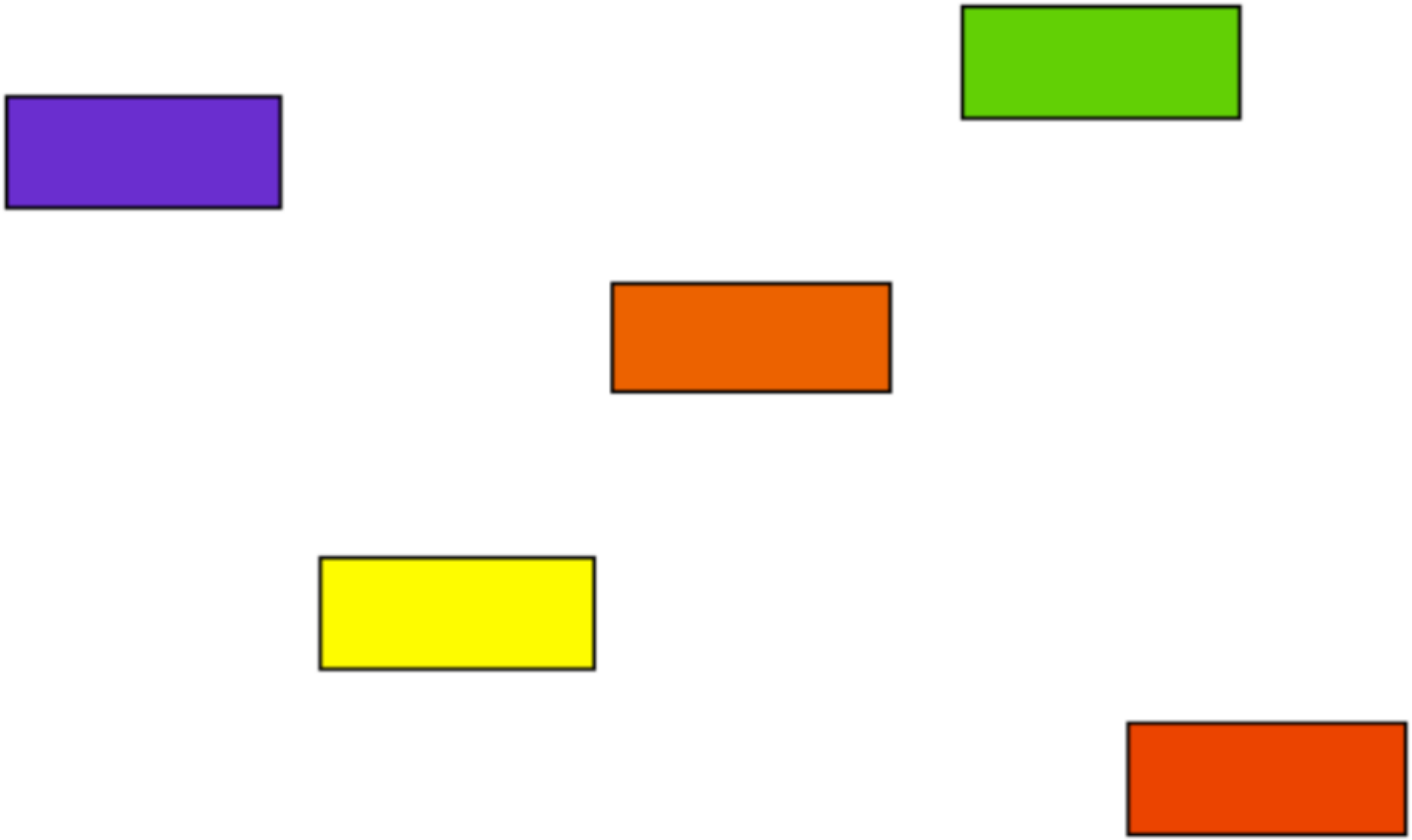
```
d3.scale.category10()
```

Order these colors!



You can’t…

Order these colors!



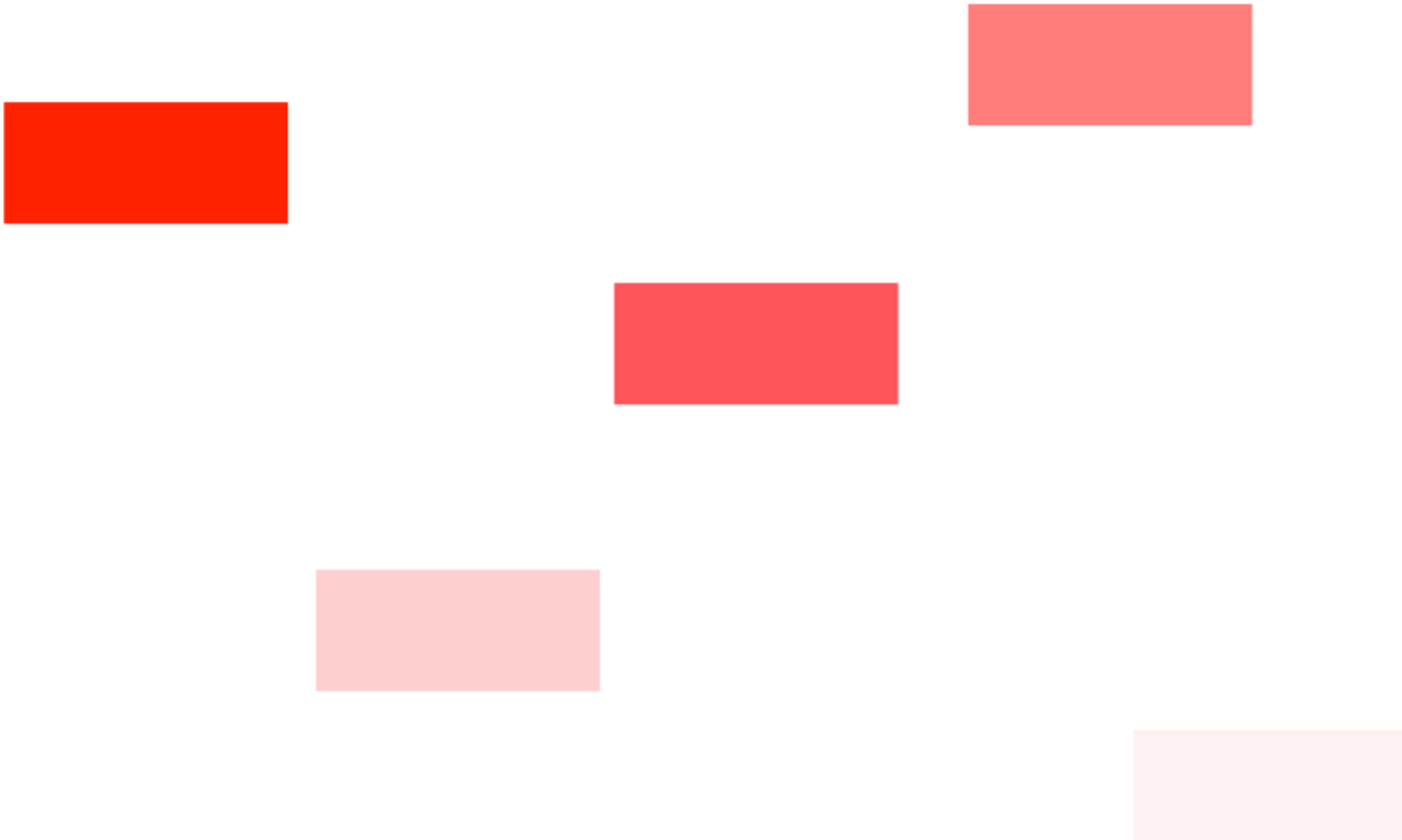
Order these colors!

You can't help but…

Order these colors!

You can't help but…

Order these colors!



Be aware of implied and perceptually forced color relationships

For categorical data, use color only when you have few categories (less than 10)

Editor:
Theresa-Marie Rhyne

Rainbow Color Map (Still) Considered Harmful

David Borland and Russell M. Taylor II
University of North Carolina at Chapel Hill

Research has shown that the rainbow color map is rarely the optimal choice when displaying data with a pseudocolor map. The rainbow color map confuses viewers through its lack of perceptual ordering, obscures data through its uncontrolled luminance variation, and actively misleads interpretation through the introduction of non-data-dependent gradients.

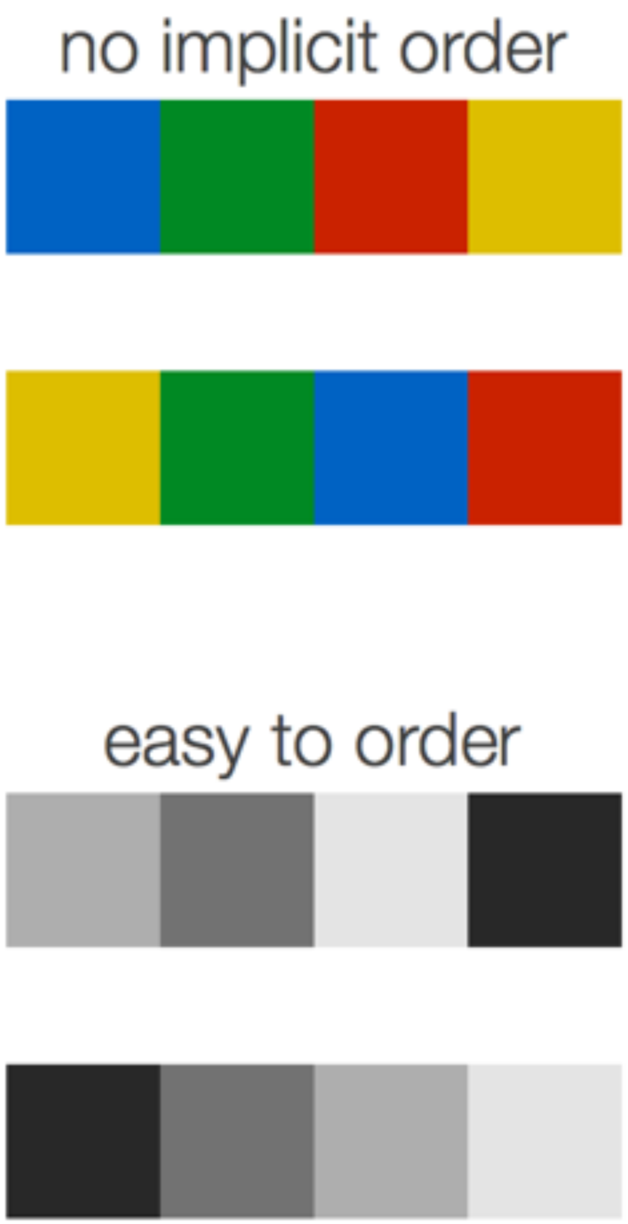
Despite much published research on its deficiencies, the rainbow color map is prevalent in the visualization community. We present survey results showing that the rainbow color map continues to appear in more than half of the relevant papers in IEEE Visualization Conference proceedings; for example, it appeared on 61 pages in 2005. Its use is encouraged by its selection as the default color map used in most visualization toolkits that we inspected. The visualization community must do better.

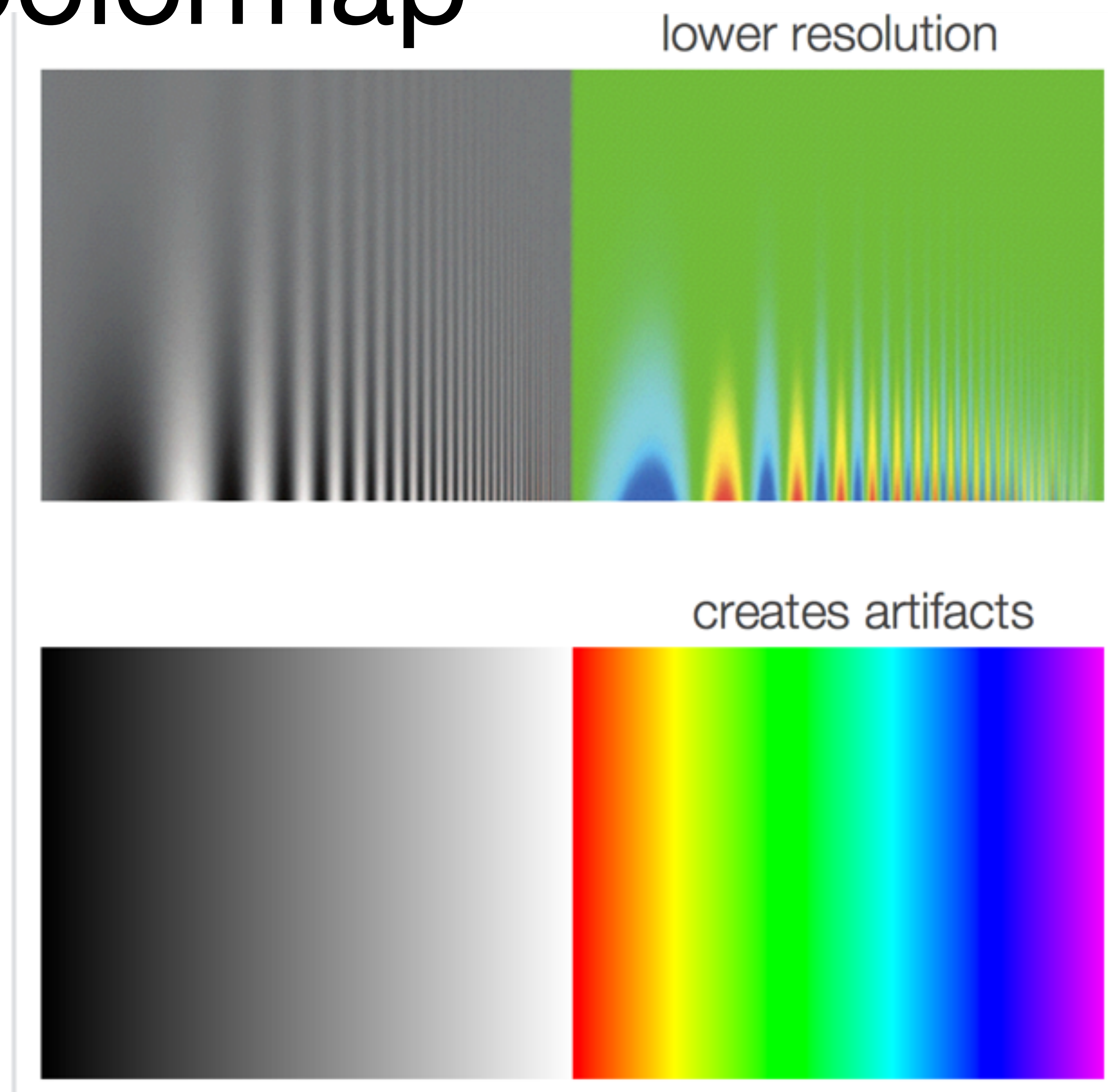
In this article, we reiterate the characteristics that mercials, weather forecasts, and even the IEEE Visualization Conference 2006 call for papers, just to name a few. The problem with this wide use of the rainbow color map is that research shows that it is rarely, if ever, the optimal color map for a given visualization.[1-6] Here we will discuss the rainbow color map's characteristics of confusing the viewer, obscuring data, and actively misleading interpretation.

Confusing

For all tasks that involve comparing relative values, the color map used should exhibit perceptual ordering. A simple example of a perceptually ordered color map is the gray-scale color map. Increasing luminance from black to white is a strong perceptual cue that indicates values mapped to darker shades of gray are lower in value than values mapped to lighter shades of gray. This mapping is natural and intuitive.

The Dreaded Rainbow Colormap

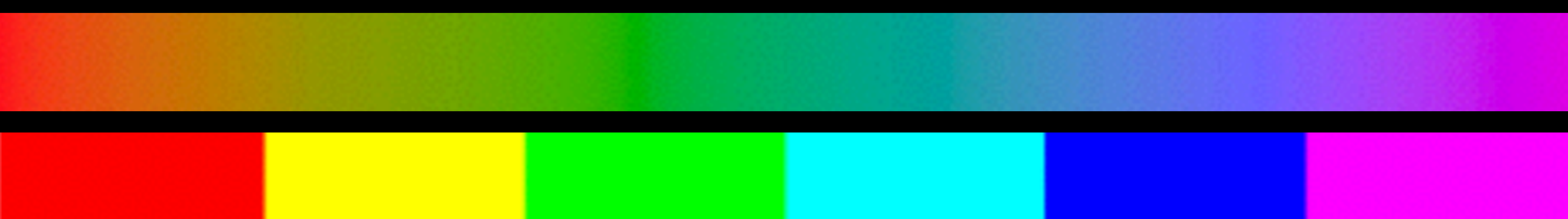




If you’re going to use the rainbow colormap, use an **isoluminant** version, **quantize** it, or **both**

Bad

Better



COLORBREWER