Data Visualization Principles: Other Perceptual Channels

CSC544

Acknowledgments for today’s lecture:
Tamara Munzner, Miriah Meyer, Colin Ware, Christopher Healey

There exist stimuli other than colors

Table 1. Representative exponents of the power functions relating subjective magnitude to stimulus magnitude

Continuum	Measured exponent	Stimulus condition
Loudness	0.67	Sound pressure of 3000-hertz tone
Vibration	0.95	Amplitude of 60 hertz on finger
Vibration	0.6	Amplitude of 250 hertz on finger
Brightness	0.33	5° Target in dark
Brightness	0.5	Point source
Brightness	0.5	Brief flash
Brightness	1.0	Point source briefly flashed
Lightness	1.2	Reflectance of gray papers
Visual length	1.0	Projected line
Visual area	0.7	Projected square
Redness (saturation)	1.7	Red-gray mixture
Taste	1.3	Sucrose
Taste	1.4	Salt
Taste	0.8	Saccharine
Smell	0.6	Heptane
Cold	1.0	Metal contact on arm
Warmth	1.6	Metal contact on arm
Warmth	1.3	Irradiation of skin, small area
Warmth	0.7	Irradiation of skin, large area
Discomfort, cold	1.7	Whole body irradiation
Discomfort, warm	0.7	Whole body irradiation
Thermal pain	1.0	Radiant heat on skin
Tactual roughness	1.5	Rubbing emery cloths
Tactual hardness	0.8	Squeezing rubber
Finger span	1.3	Thickness of blocks
Pressure on palm	1.1	Static force on skin
Muscle force	1.7	Static contractions
Heaviness	1.45	Lifted weights
Viscosity	0.42	Stirring silicone fluids
Electric shock	3.5	Current through fingers
Vocal effort	1.1	Vocal sound pressure
Angular acceleration	1.4	5-Second rotation
Duration	1.1	White noise stimuli

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So what is data visualization?

The art and science of matching the “features” of a data set to the “features” of visual perception

Why visualization?

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An Introduction to Interactive Sonification

Thomas Hermann
Bielefeld University, Germany

Andy Hunt
University of York, UK

The research field of sonification, a subset of the topic of auditory display, has developed rapidly in recent decades. It brings together interests from the areas of data mining, exploratory data analysis, human–computer interfaces, and computer music. Sonification presents information by using sound (particularly nonspeech), so that the user of an auditory display obtains a deeper understanding of the data or processes under investigation by listening.[1]

We define *interactive sonification* as the use of sound within a tightly closed human–computer interface where the auditory signal provides information about data under analysis, or about the interaction itself, which is useful for refining the activity.

work processes. For the newer applications, the data often have a high dimensionality. This has led to two trends:

- the development of techniques to achieve dimensionality reduction without losing the available information in the data, and
- the search for techniques to represent more dimensions at the same time.

Regarding the latter point, auditory displays offer an interesting complement to visual displays. For example, an acoustic event (the audio counterpart of the graphical symbol) can show variation in a multitude of attributes such as pitch, modulations, amplitude envelope over time, spatial location, timbre, and brightness simultaneously.

Human perception, though, is tuned to process a combined audiovisual (and often also tactile and olfactory) experience that changes instantaneously as we perform actions. Thus we can increase the dimensionality further by using different modalities for data representation. The more we understand the interaction of these different modalities in the context of human activity in the real world, the more we learn what conditions are best for using them to present and interact with high-dimensional data.

Interacting with musical interfaces

Throughout history humankind has developed tools that help us shape and understand the world. We use these in a close action-perception loop, where physical interaction yields continuous visual, tactile, and sonic feedback. Musical instruments are particularly good examples of systems where the acoustic feedback plays an impor-

Why visualization?

- It has been studied more deeply
- It appears to have more “bandwidth” than alternatives (though not as much as you think it does)
- It is **richer**

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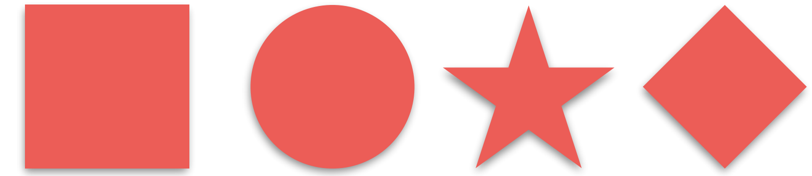
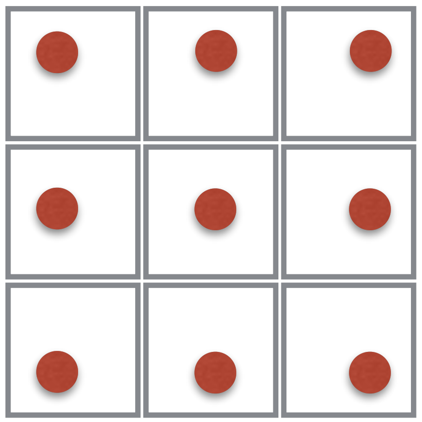
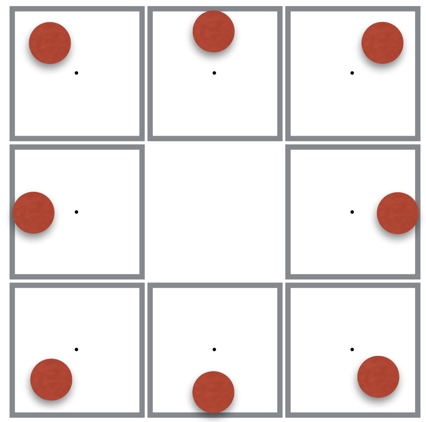
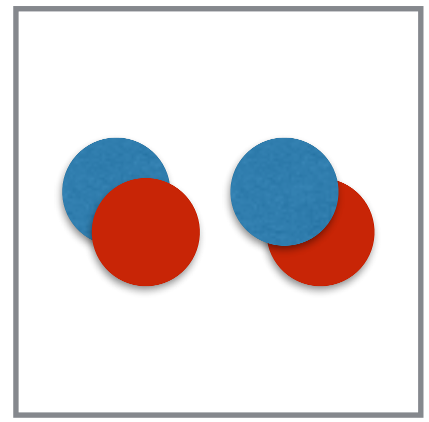
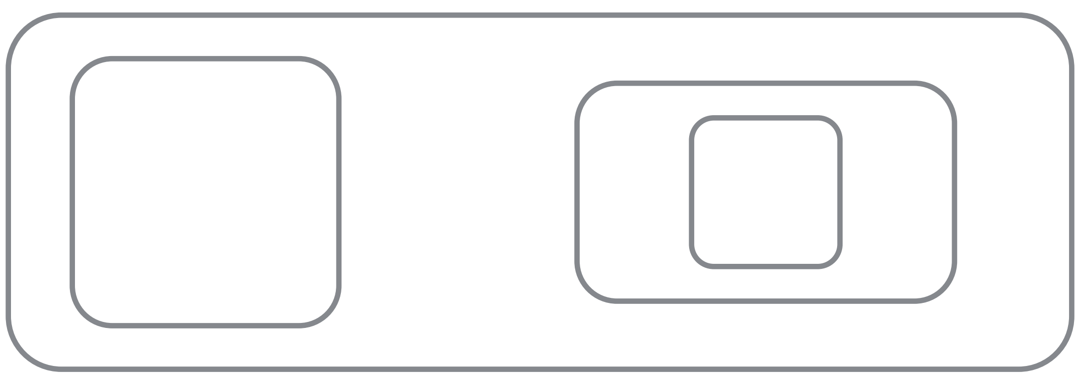
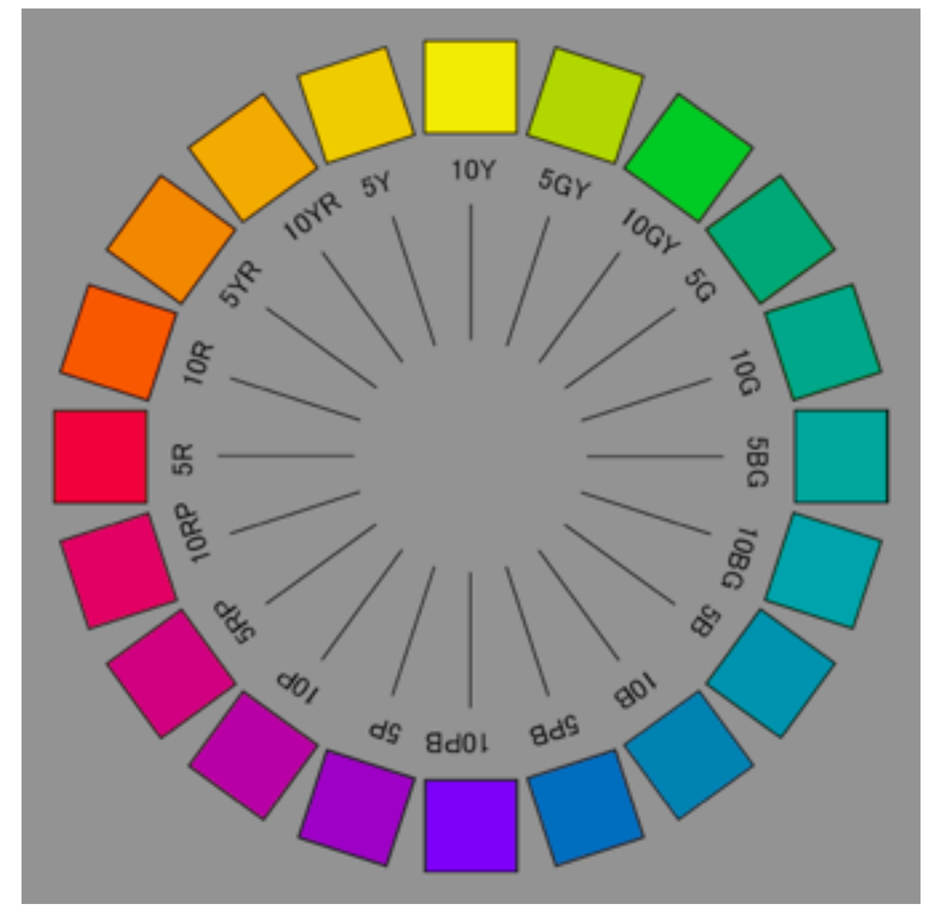












(c) PlusMinus, GFDL

Integral vs. Separable Channels

- Do humans perceive values “as a whole”, or “as things that can be split”?

  - **“Is it a vector, or is it a pair?”**

Integral vs. Separable Channels

Separable ⟷ Integral

color x location

color x motion

color x shape

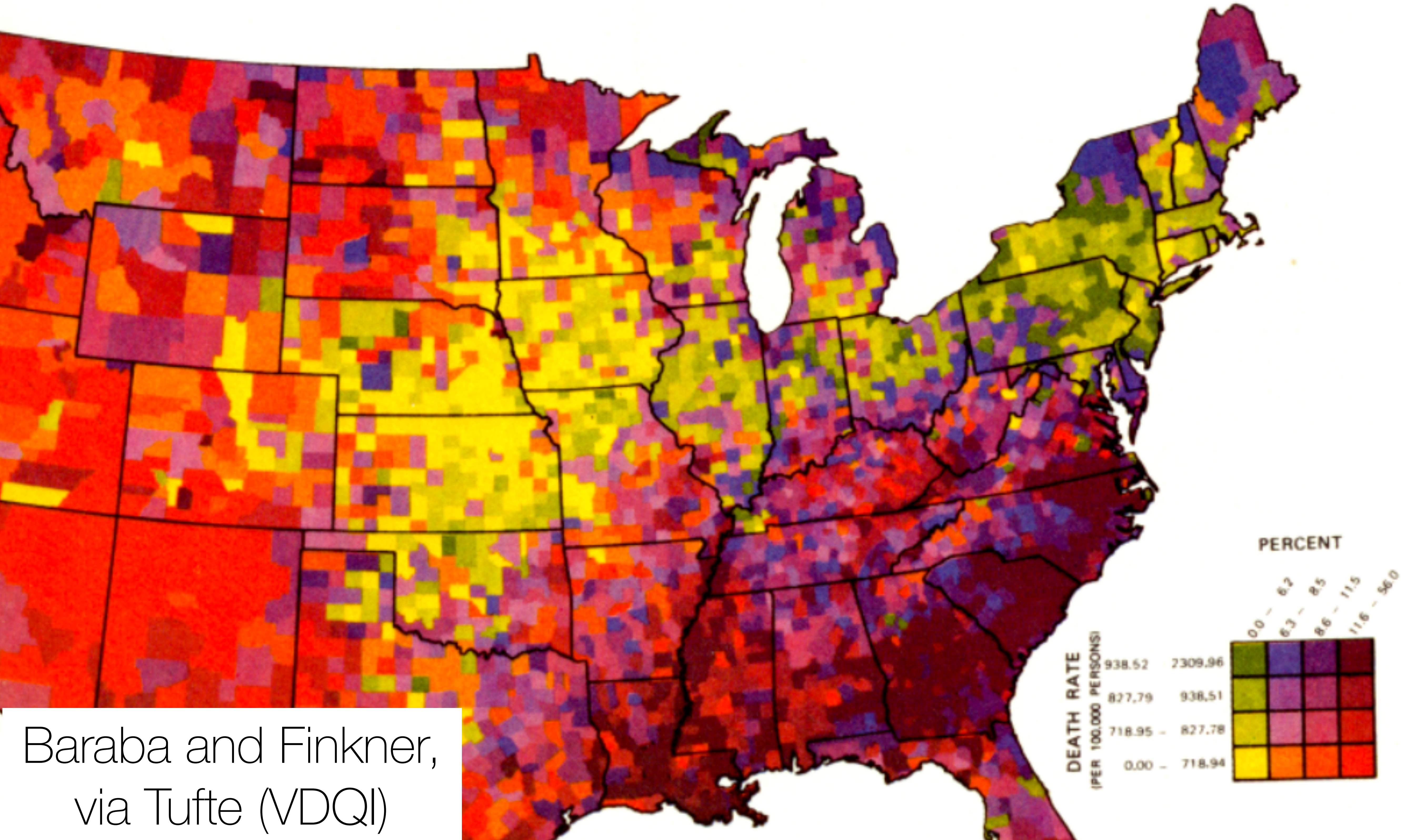
size x orientation

x-size x y-size

r-g x y-b

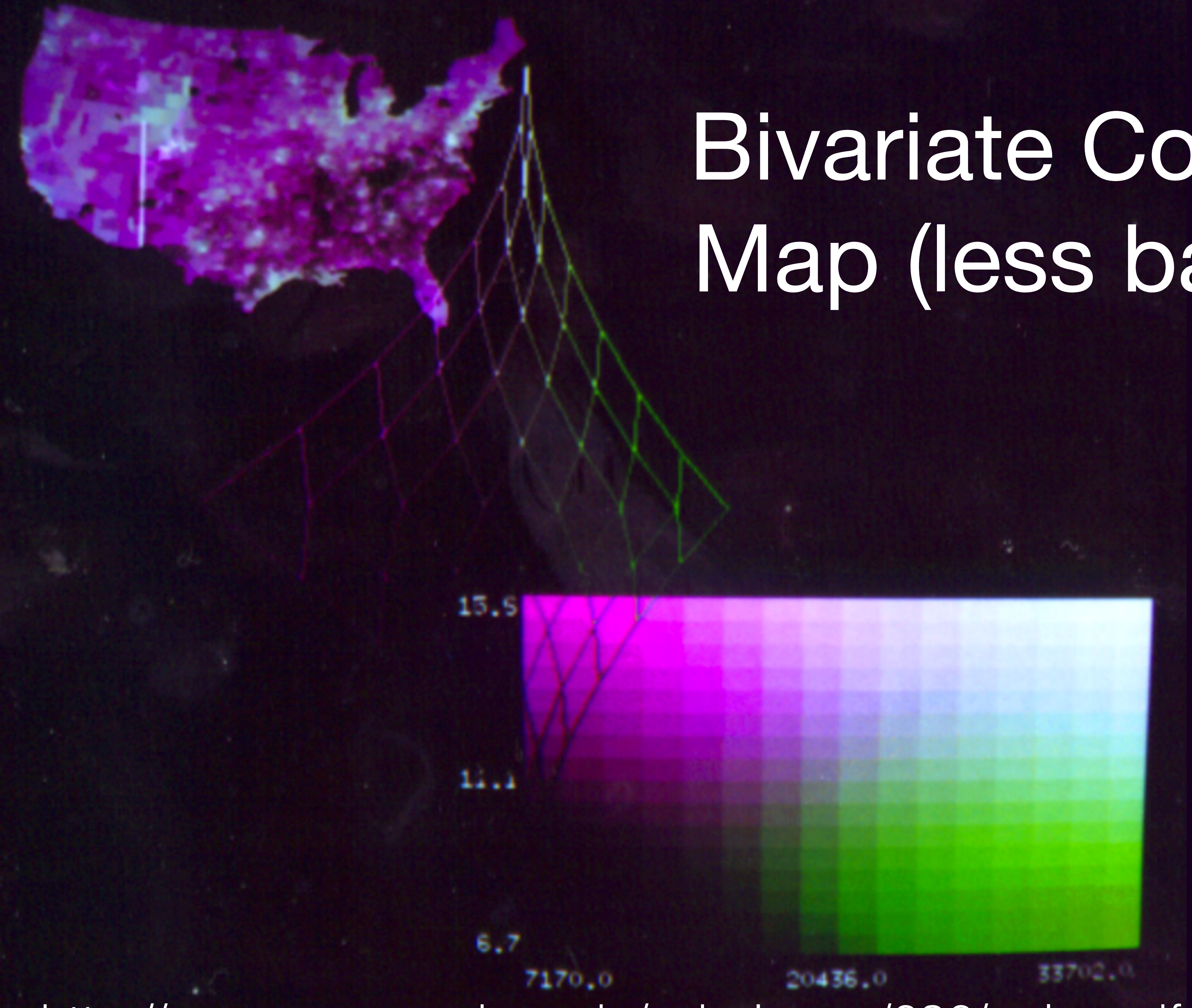
Colin Ware, 2004, p180

Bivariate Color Map (Bad)

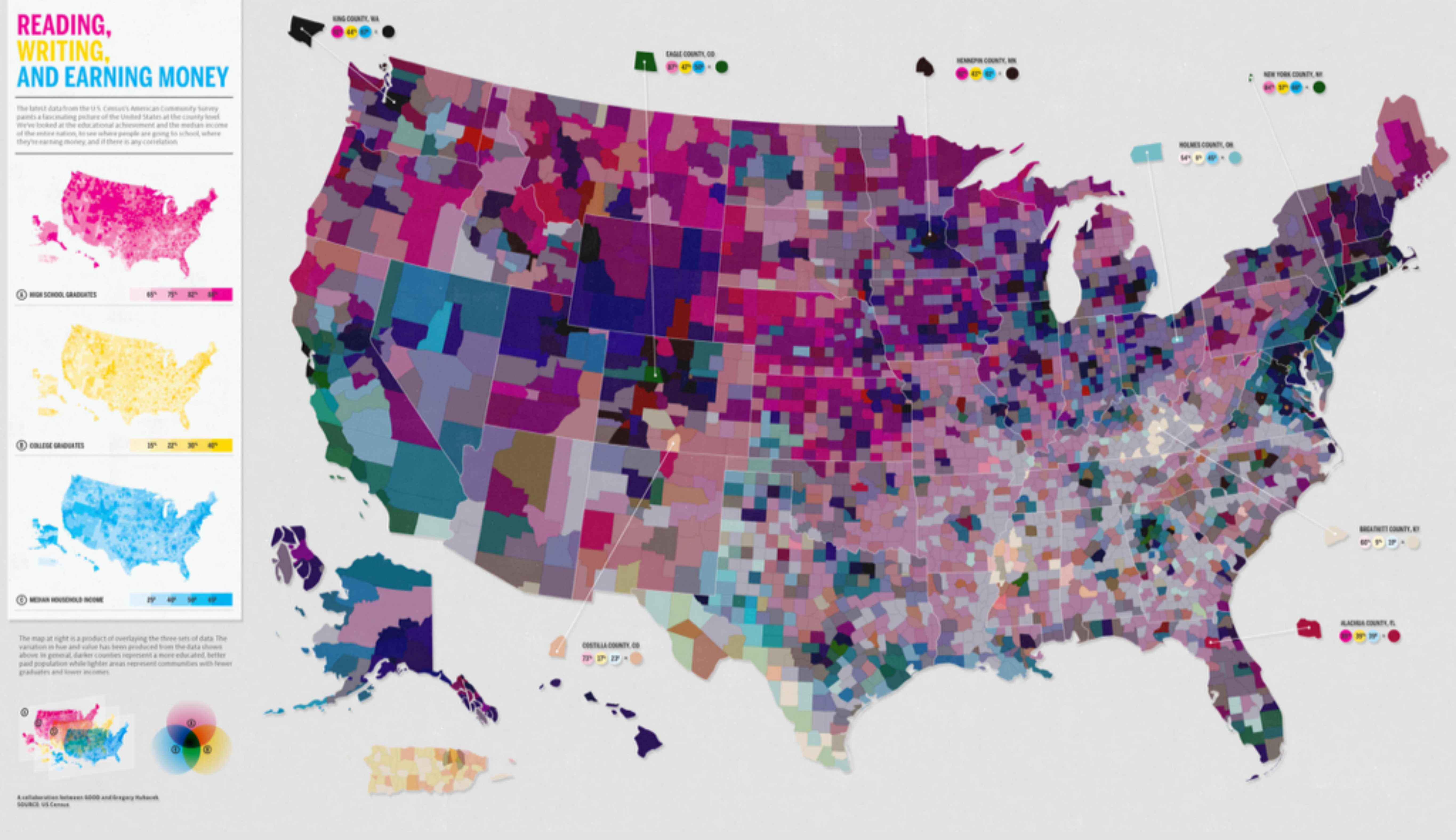


Baraba and Finkner,
via Tufte (VDQI)

Bivariate Color Map (less bad)



http://www.csee.umbc.edu/~rheingan/636/color.pdf

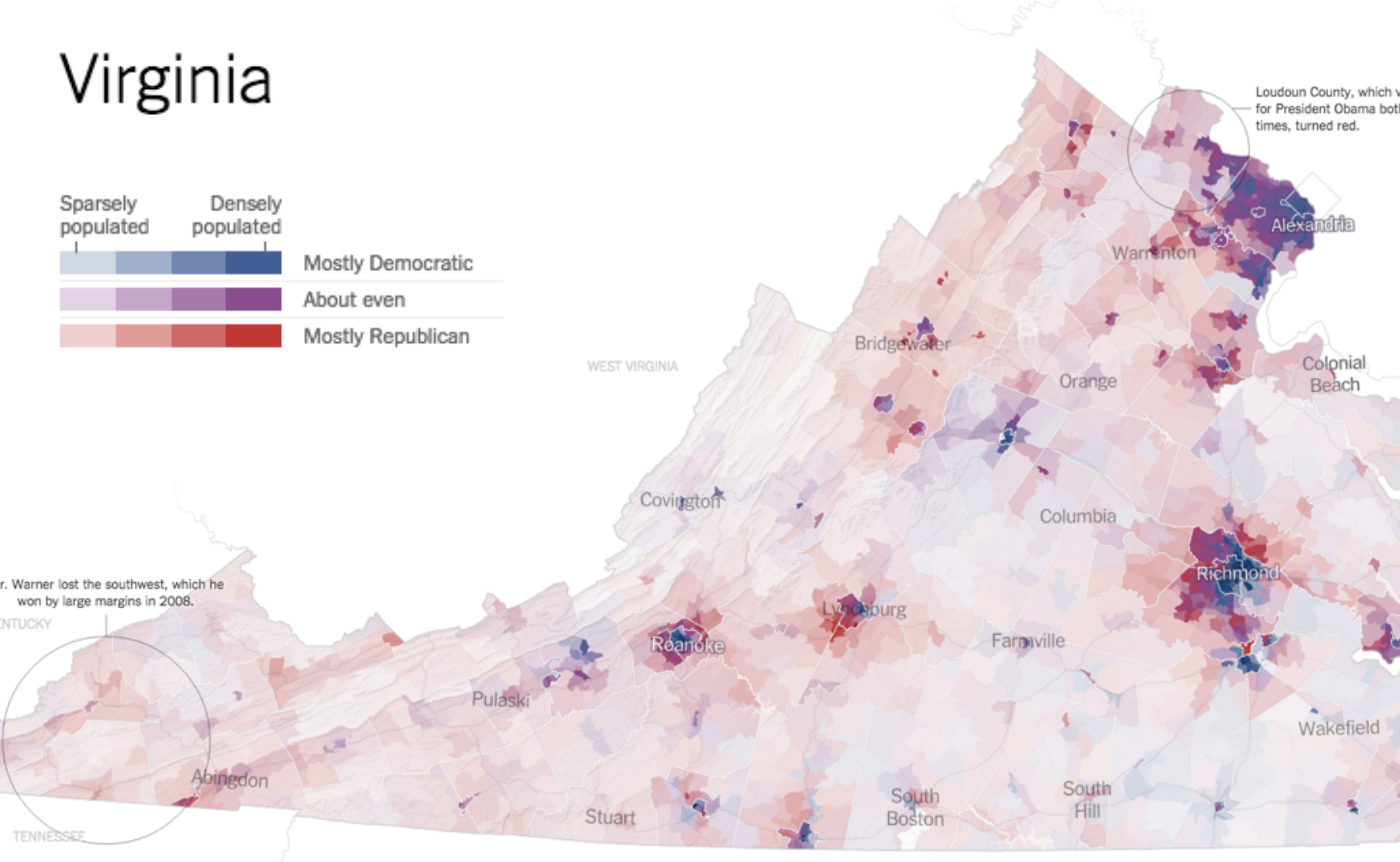


Trivariate (!) Color Map (terrible, terrible idea)

http://magazine.good.is/infographics/america-s-richest-counties-and-best-educated-counties#open

The best bivariate colormap I know

http://www.nytimes.com/interactive/2014/11/04/upshot/senate-maps.html



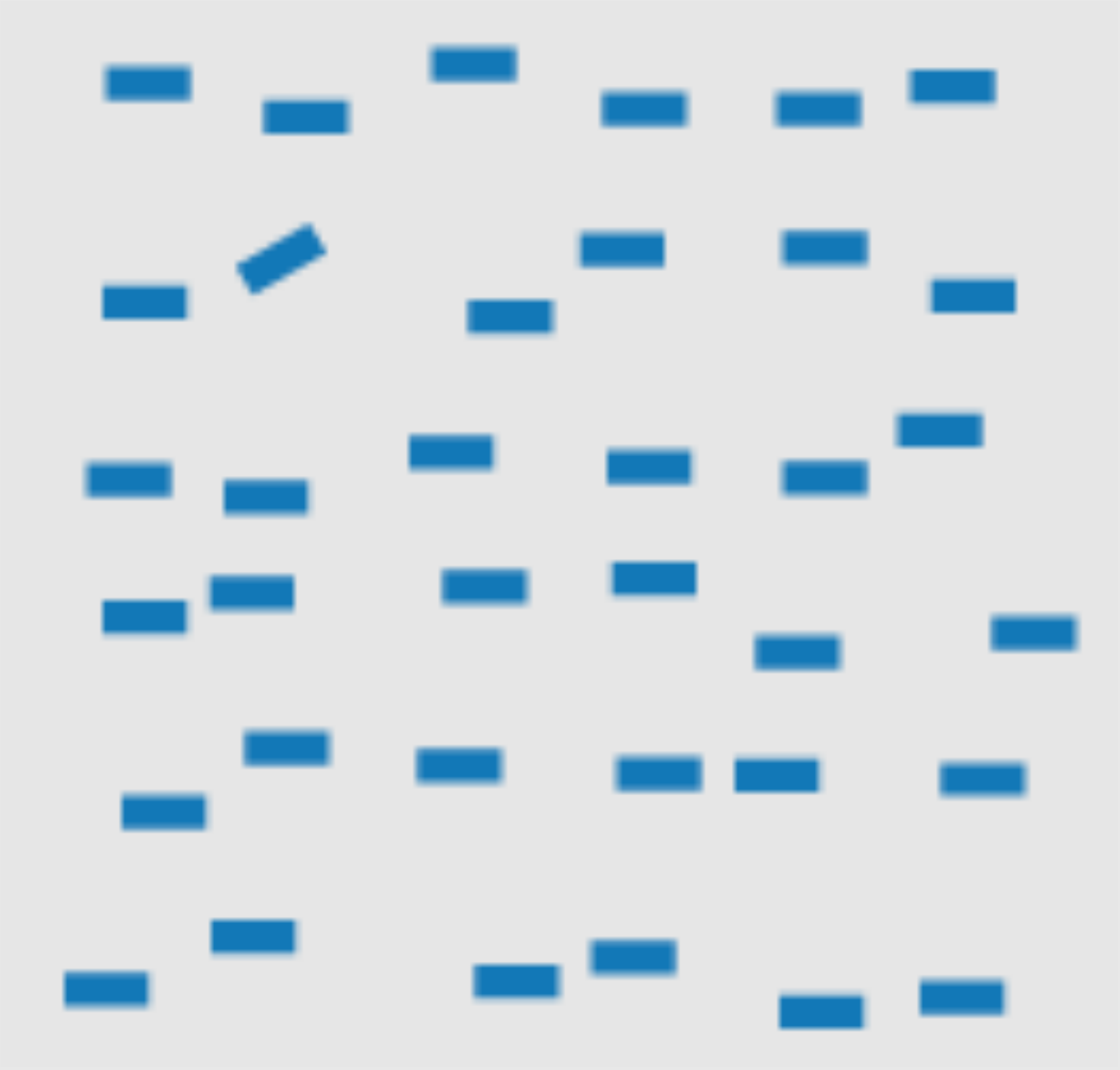
Bivariate Color Maps are Possible, but Hard

pay attention to the **behavior of the variables** you’re mapping from, and the **behavior of the channels** you’re mapping to.

PREATTENTIVENESS,

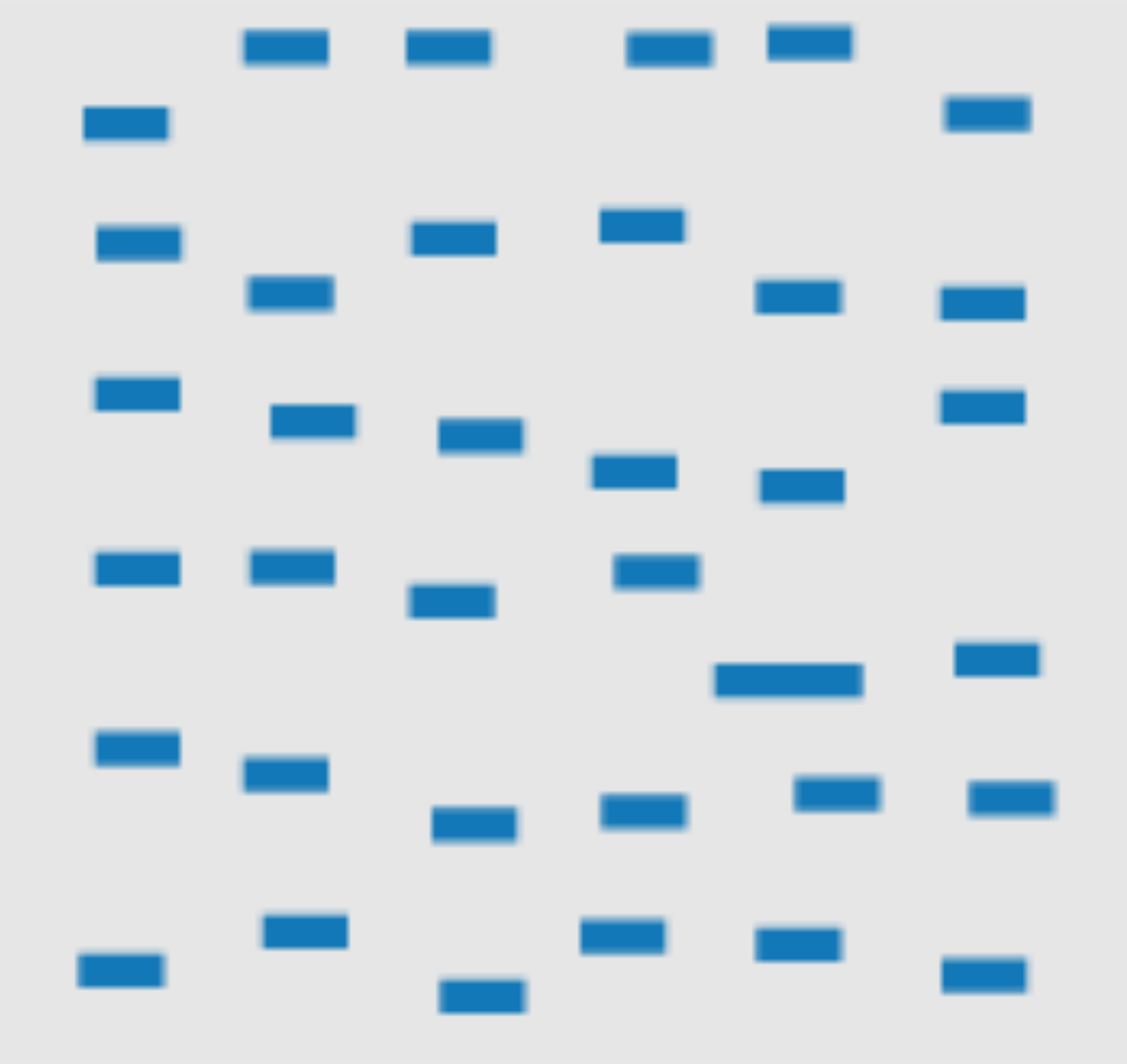
OR "VISUAL POP-OUT"

ORIENTATION



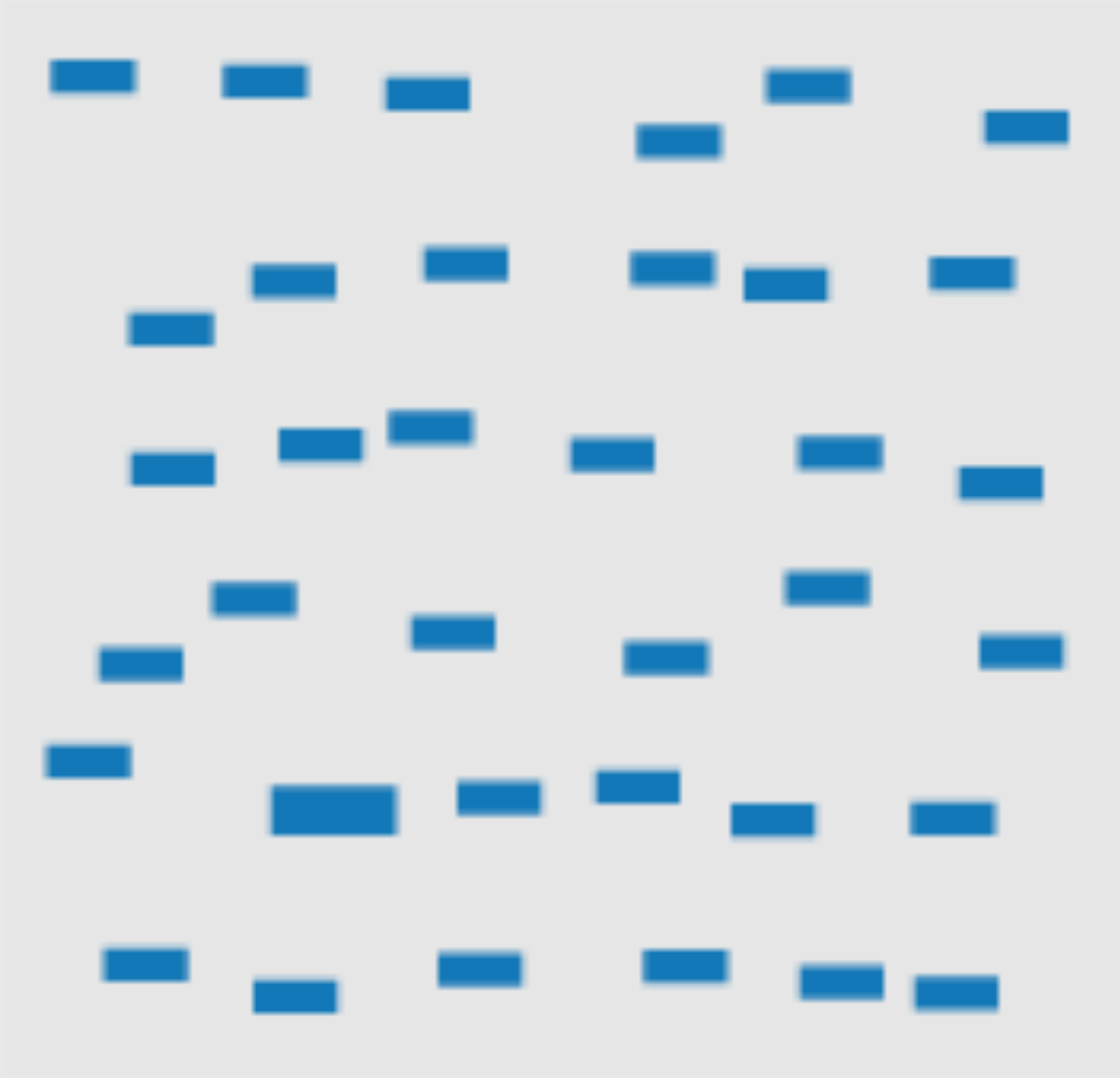
Christopher Healey, http://www.csc.ncsu.edu/faculty/healey/PP/index.html

WIDTH/LENGTH

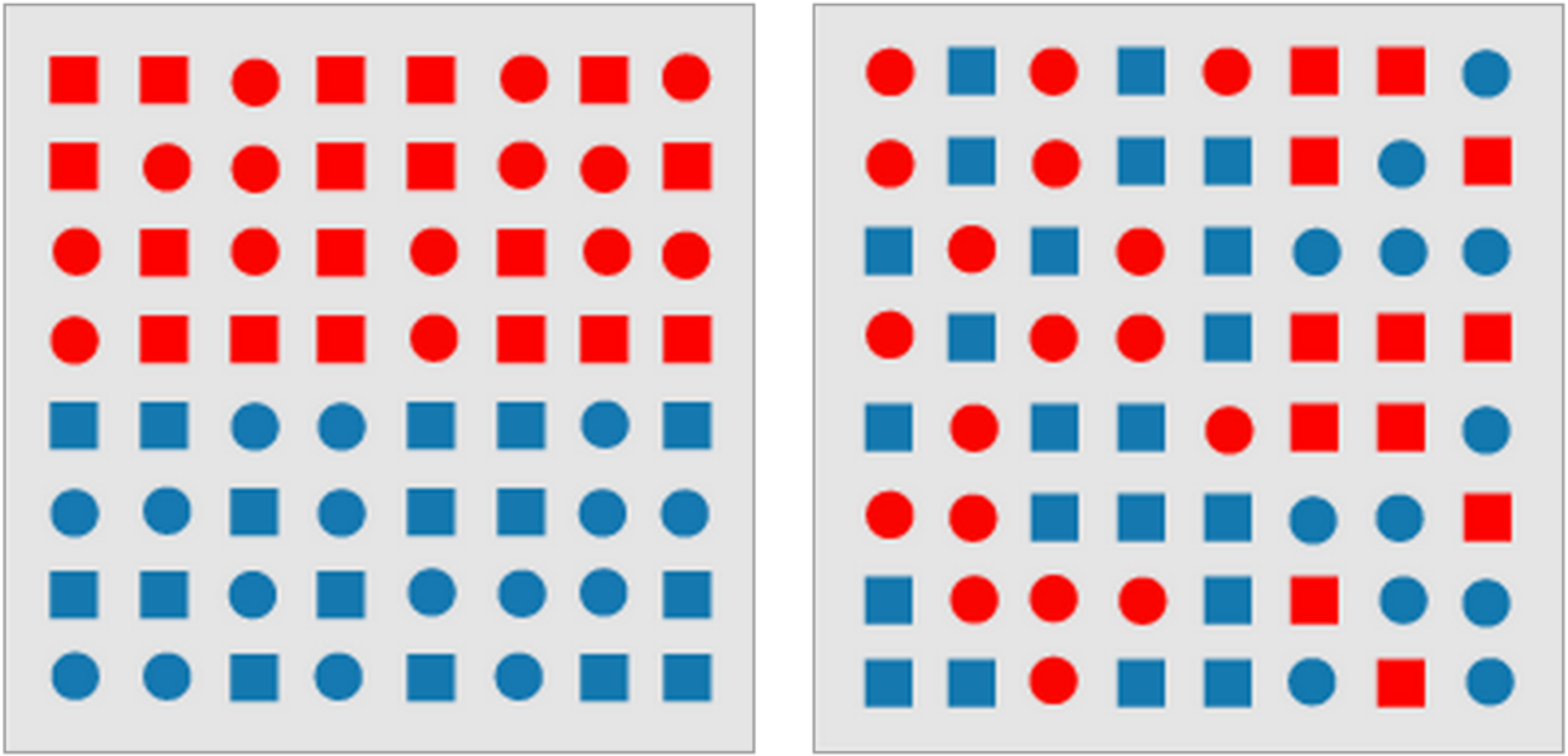


Christopher Healey, http://www.csc.ncsu.edu/faculty/healey/PP/index.html

SIZE



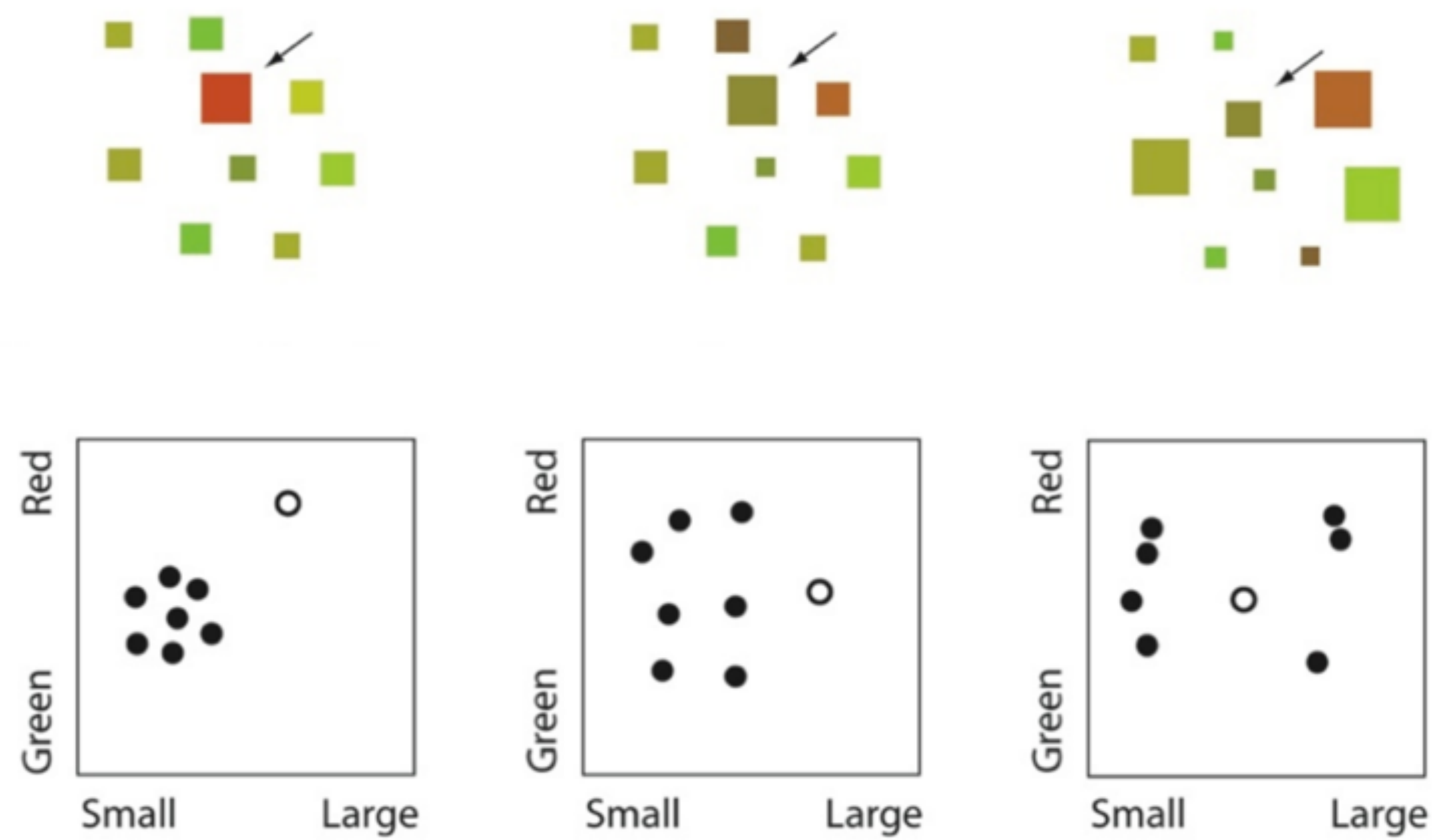
Christopher Healey, http://www.csc.ncsu.edu/faculty/healey/PP/index.html



(a) (b)

https://cscheid.net/courses/spr15/cs444/lectures/week8/preattentive.html

Mixing is not always pre-attentive

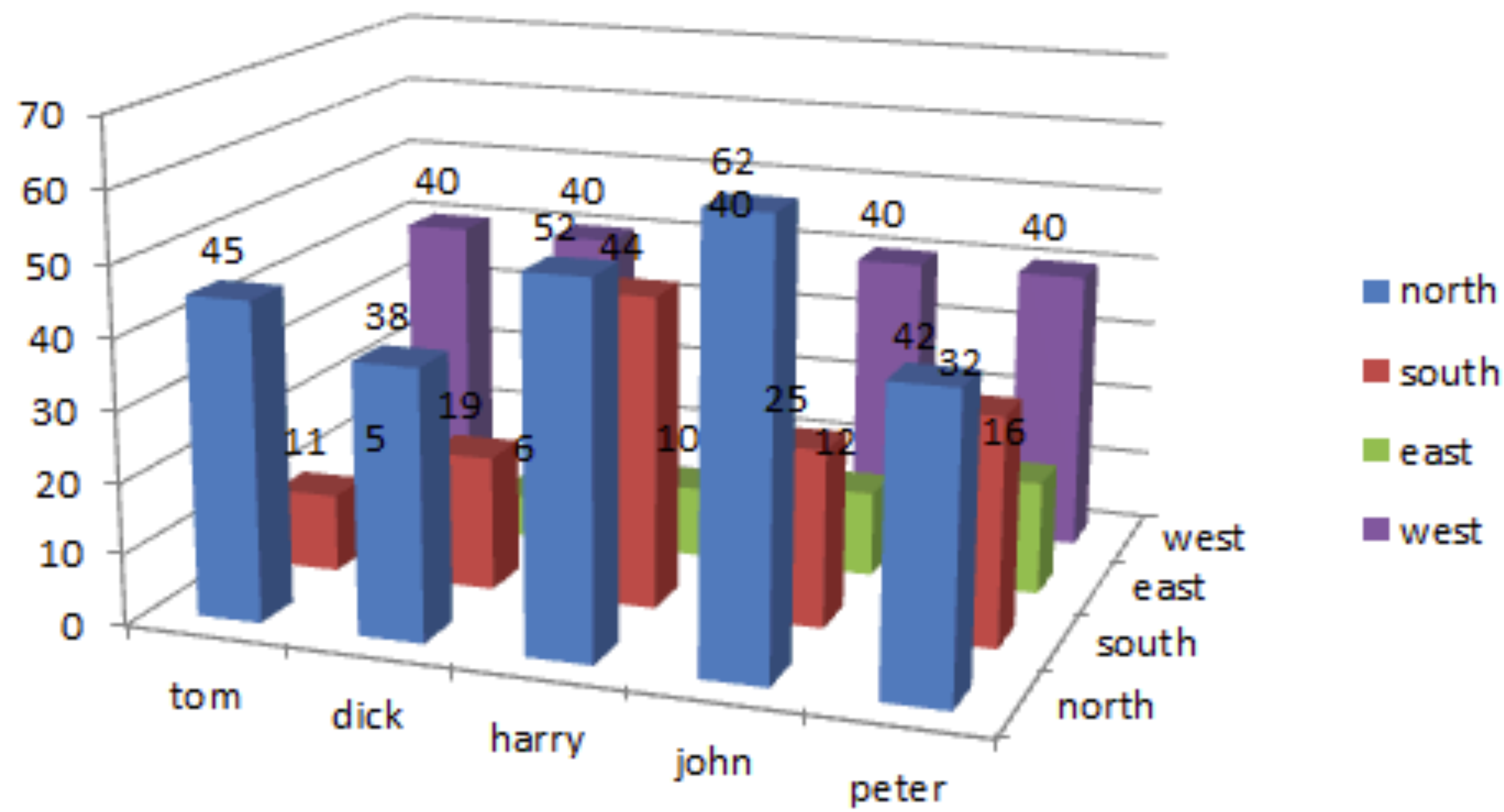


Preattentiveness is only simple to understand when considering one channel at a time.

VISUAL CHANNELS YOU SHOULD BE CAREFUL WITH, EVEN IN ISOLATION

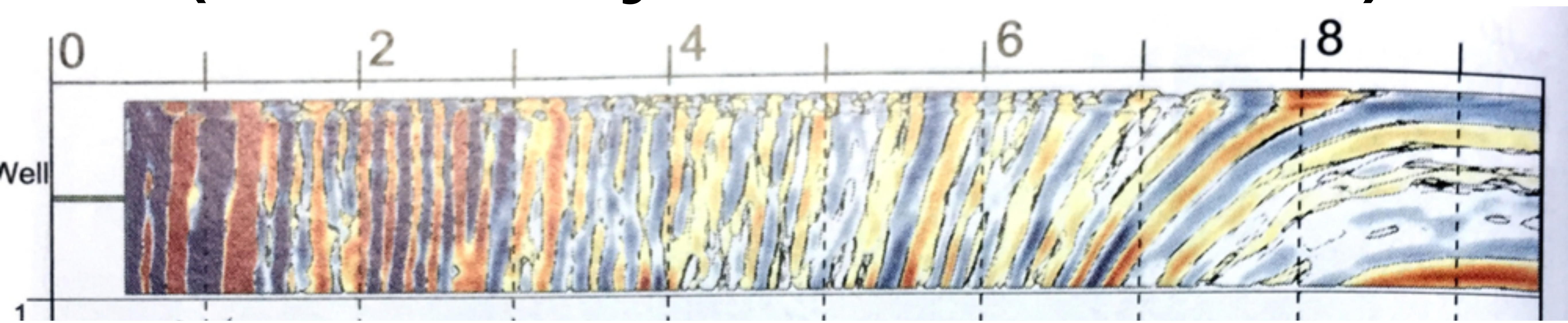
3D, when data isn’t

- Perspective interacts with size and color judgments
- Occlusion is bad, often unnecessary



Naomi Robbins, forbes.com

(and maybe even it is!)



Daae Lampe et al. TVCG 2009

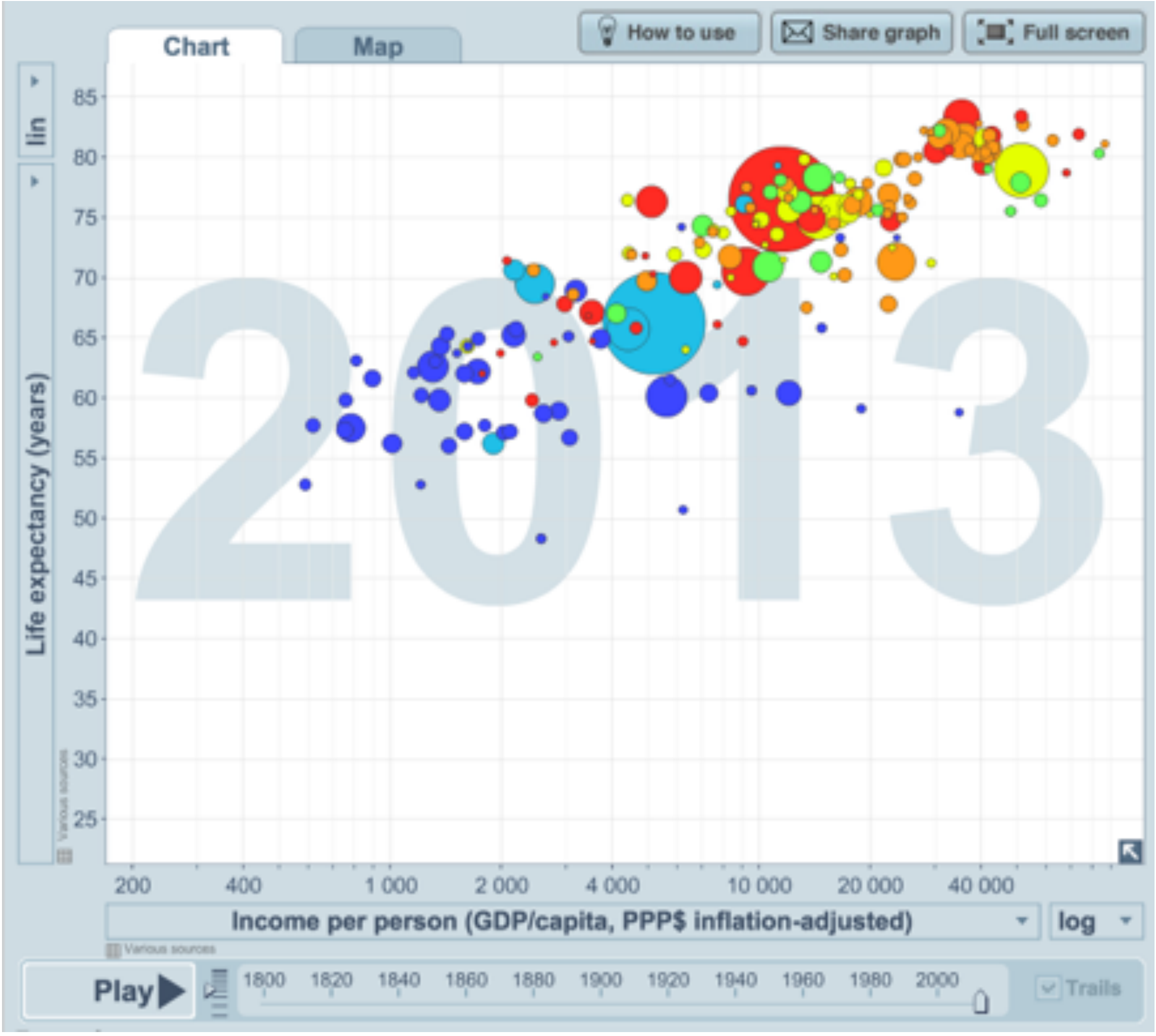
Animations

- We perceive motion, and regularity, even when none might be intended

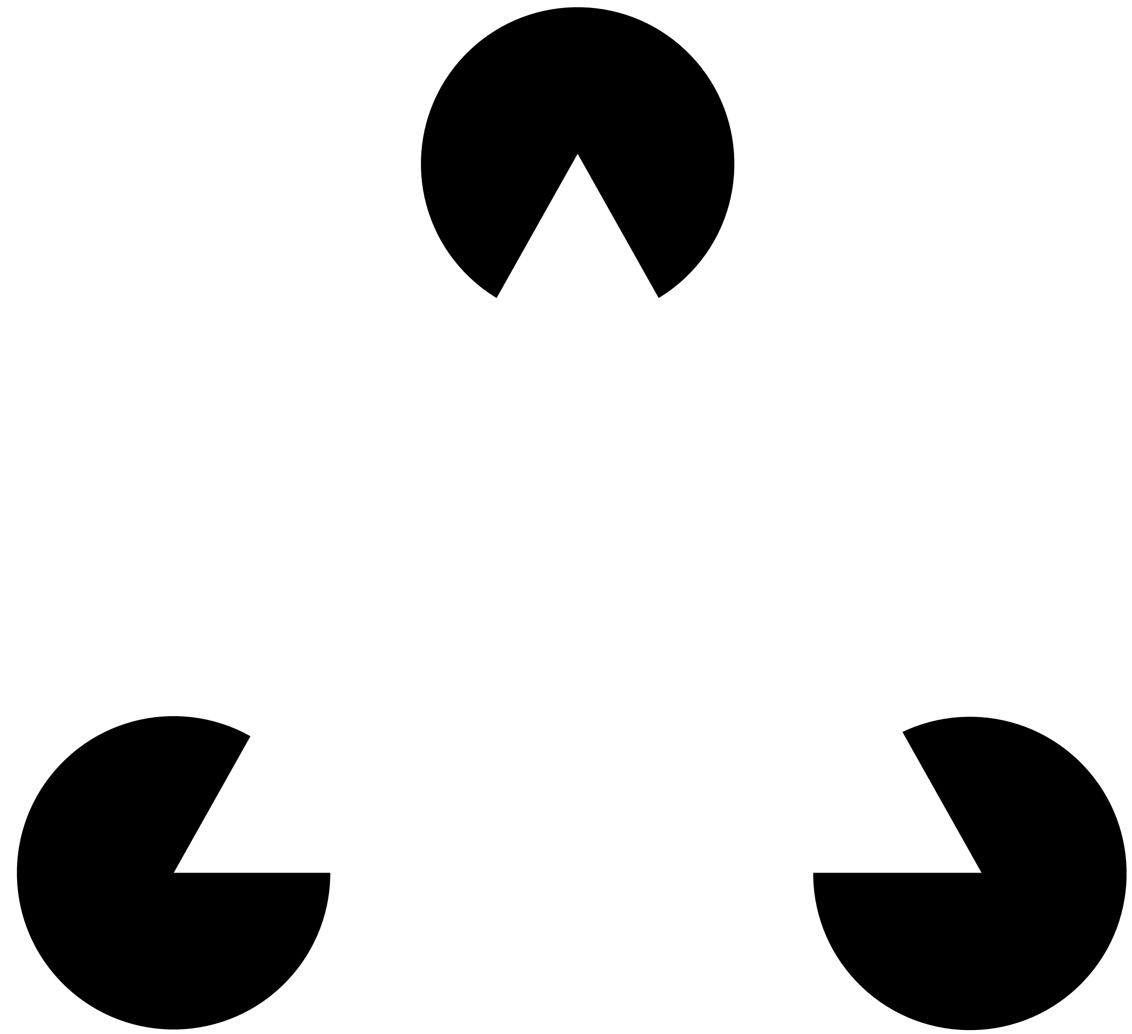
- http://en.wikipedia.org/wiki/File:Lilac-Chaser.gif
    - And it interacts badly with the rest of our perceptual system

Animations

- limit them to **data transitions**, preferably controlled by interaction



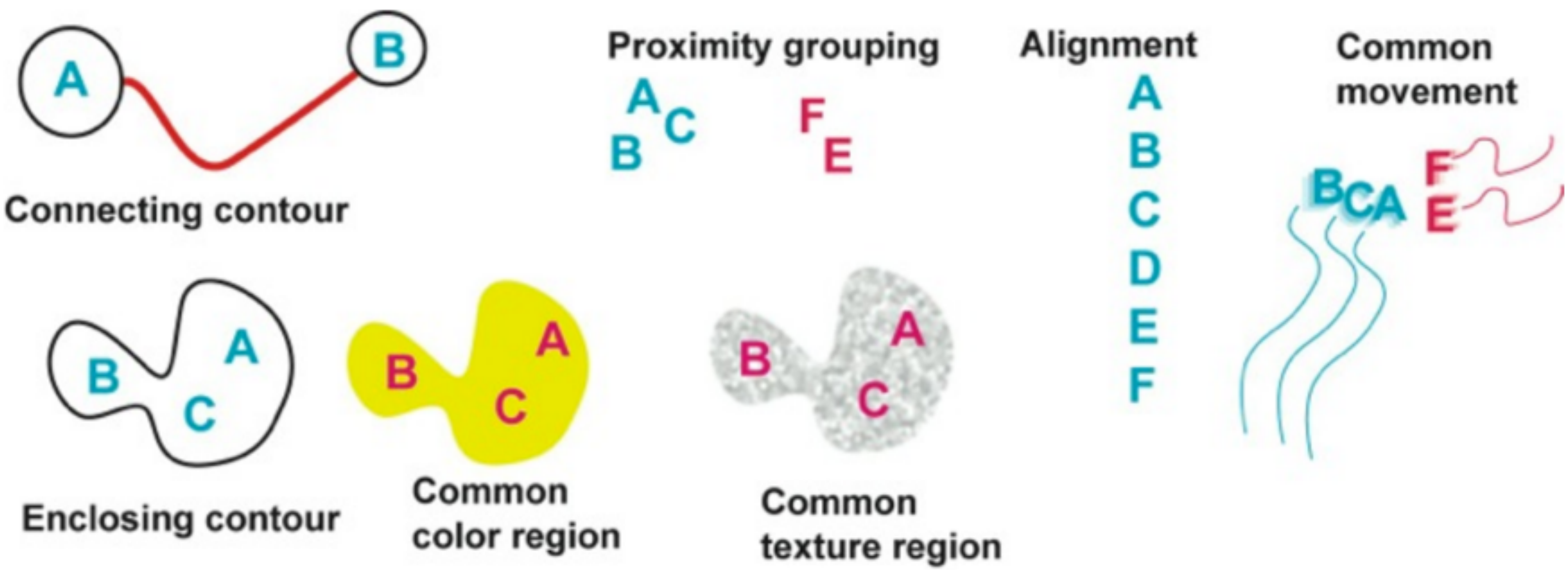
www.gapminder.org



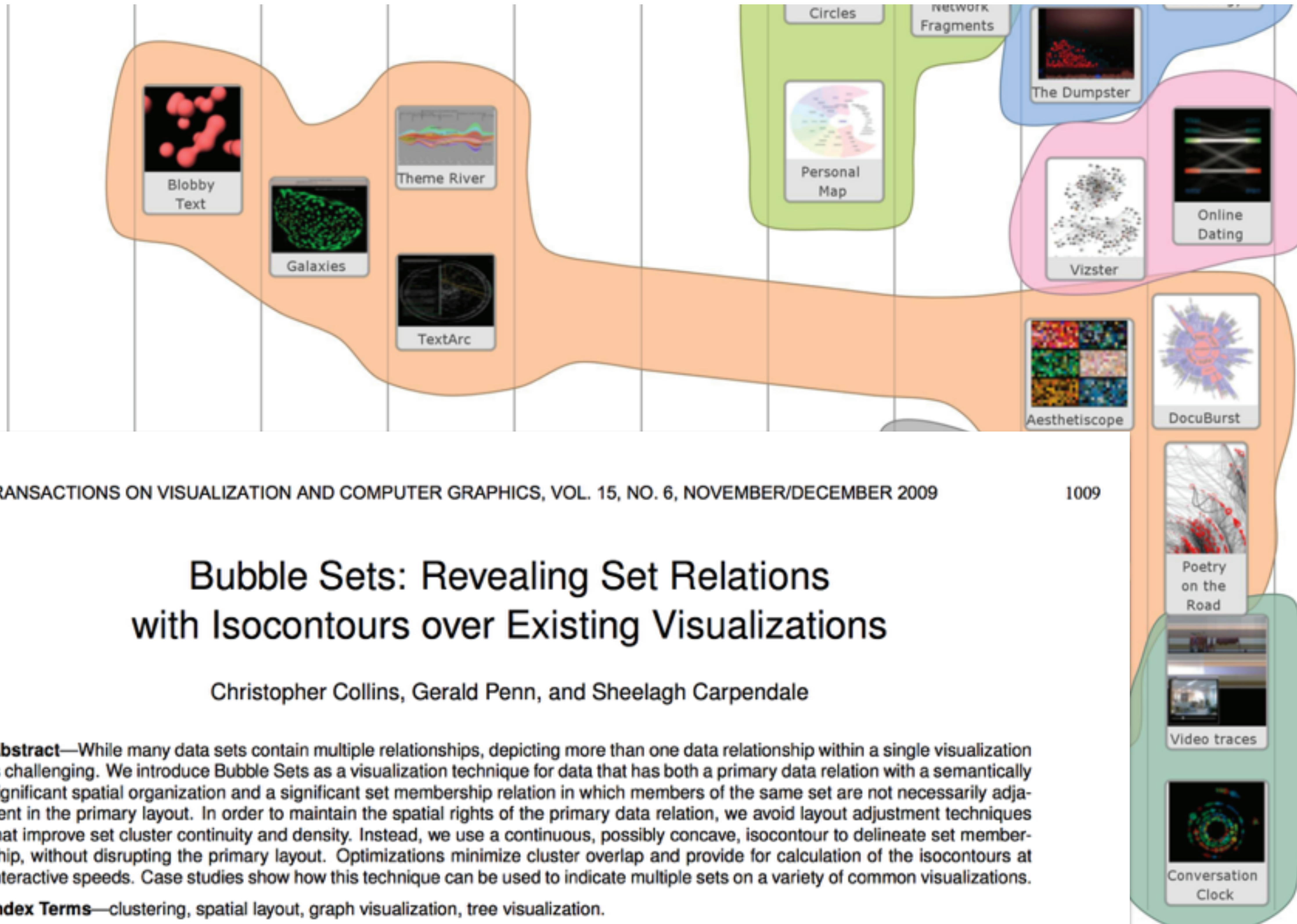
GESTALT

GESTALT PRINCIPLES

- General idea: we interpret stimuli as patterns that are grouped, complete, whole
    - Even when they maybe aren't



CONTAINMENT



IEEE TRANSACTIONS ON VISUALIZATION AND COMPUTER GRAPHICS, VOL. 15, NO. 6, NOVEMBER/DECEMBER 2009 1009

Bubble Sets: Revealing Set Relations with Isocontours over Existing Visualizations

Christopher Collins, Gerald Penn, and Sheelagh Carpendale

Abstract—While many data sets contain multiple relationships, depicting more than one data relationship within a single visualization is challenging. We introduce Bubble Sets as a visualization technique for data that has both a primary data relation with a semantically significant spatial organization and a significant set membership relation in which members of the same set are not necessarily adjacent in the primary layout. In order to maintain the spatial rights of the primary data relation, we avoid layout adjustment techniques that improve set cluster continuity and density. Instead, we use a continuous, possibly concave, isocontour to delineate set membership, without disrupting the primary layout. Optimizations minimize cluster overlap and provide for calculation of the isocontours at interactive speeds. Case studies show how this technique can be used to indicate multiple sets on a variety of common visualizations.

Index Terms—clustering, spatial layout, graph visualization, tree visualization.

HIGHER-LEVEL CHANNELS WE ARE STILL STUDYING

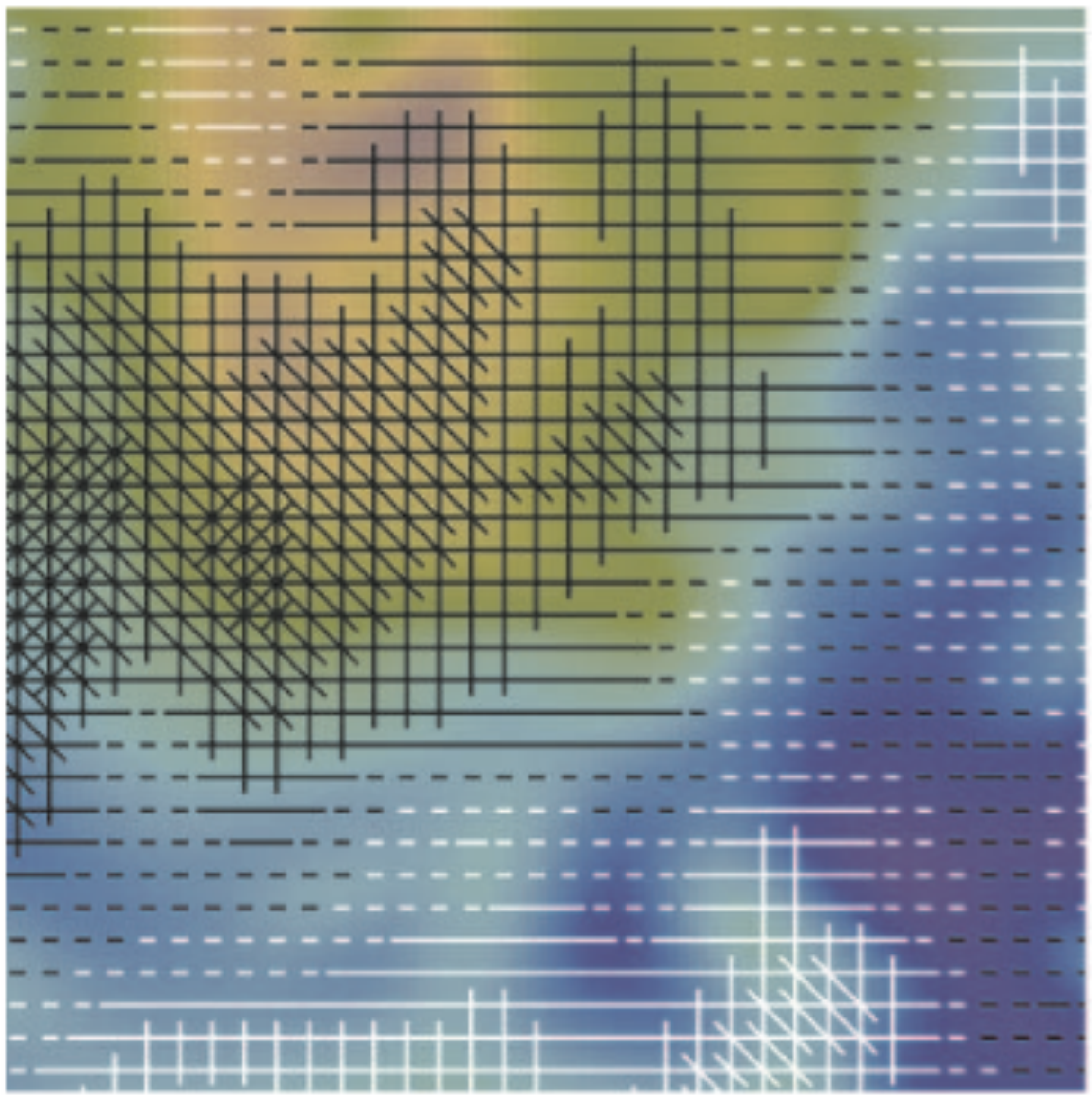
Overlays for bivariate maps

Scheme 1: Green Red (GR)

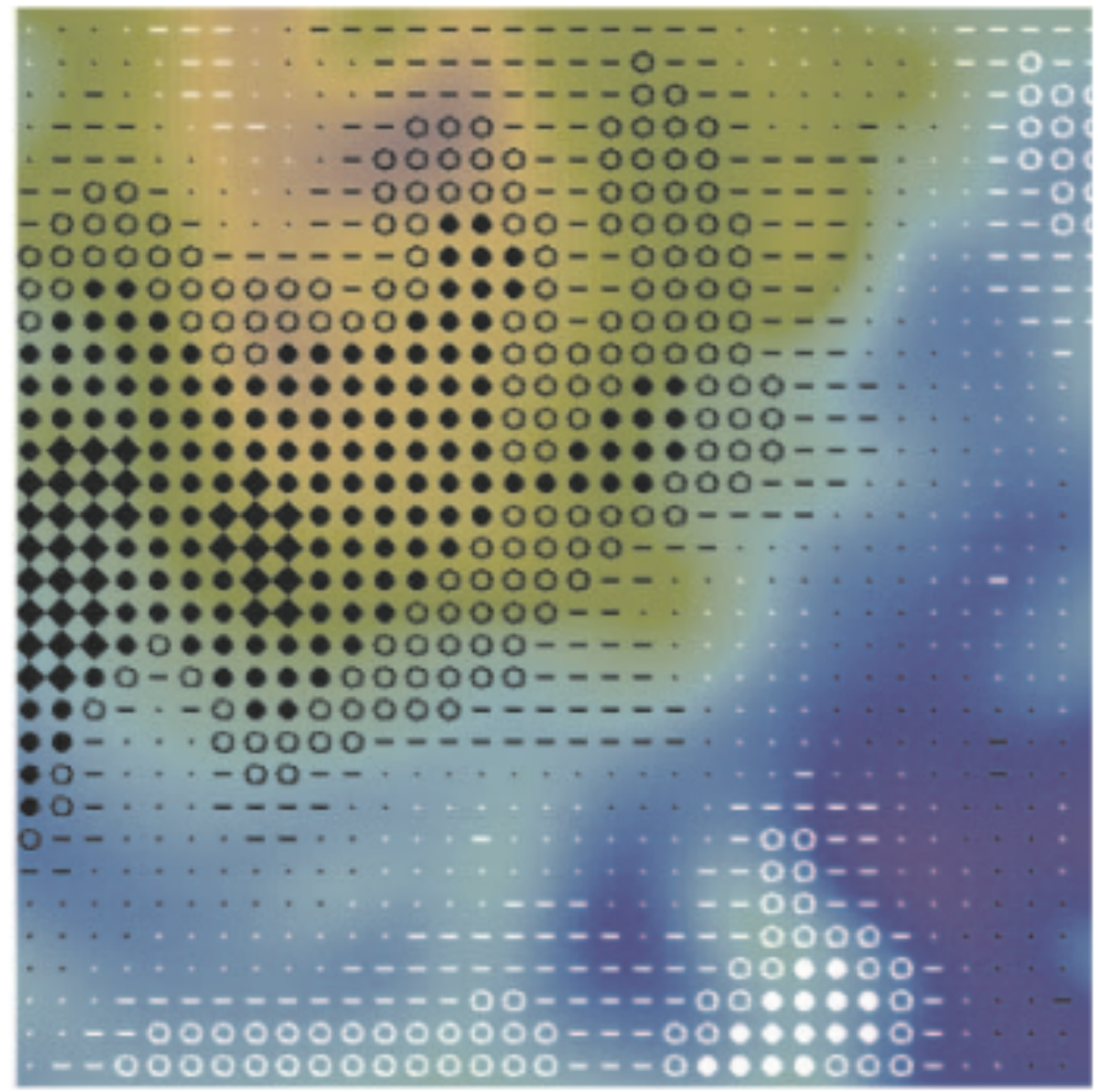
Scheme 2: Hue Lightness (HL)

Ware 2009 TVCG

Overlays for bivariate maps



Scheme 4: Spectrum QTonS 1 (QTS_1)

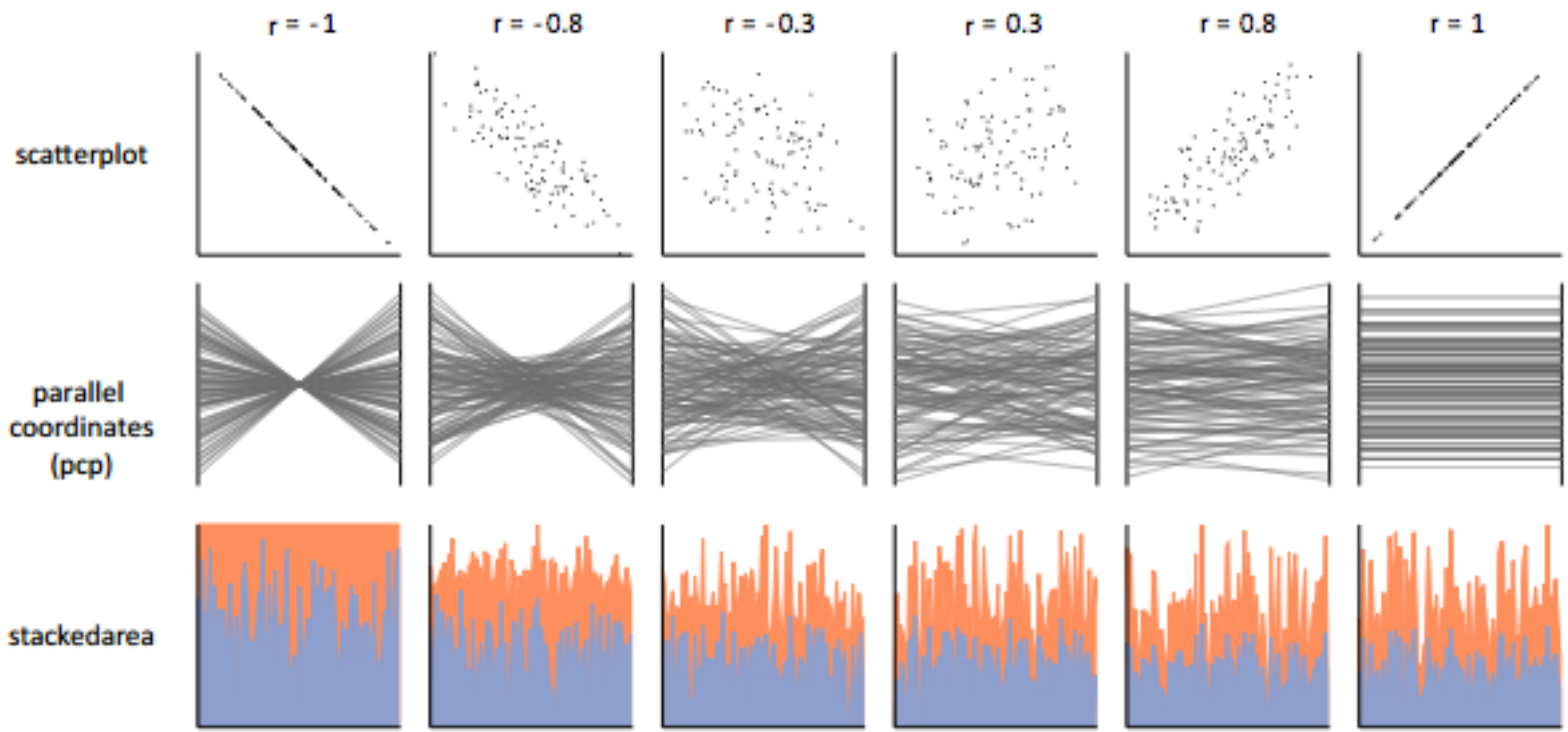


Scheme 5: Spectrum QTonS 2 (QTS_2)

Ware 2009 TVCG

Perception of higher-level features

- Correlation perception follows Weber's Law (!)



Harrison et al., TVCG 2014

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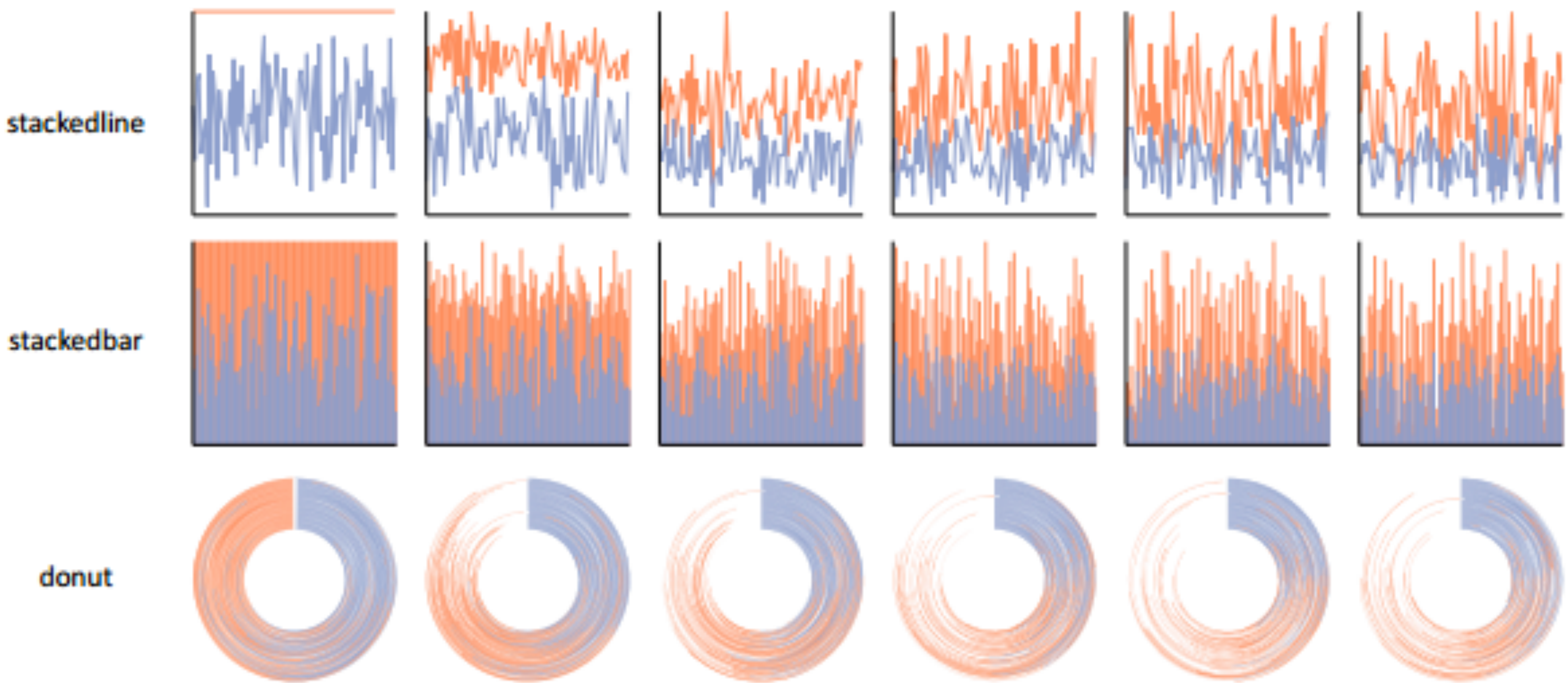

Harrison et al., TVCG 2014

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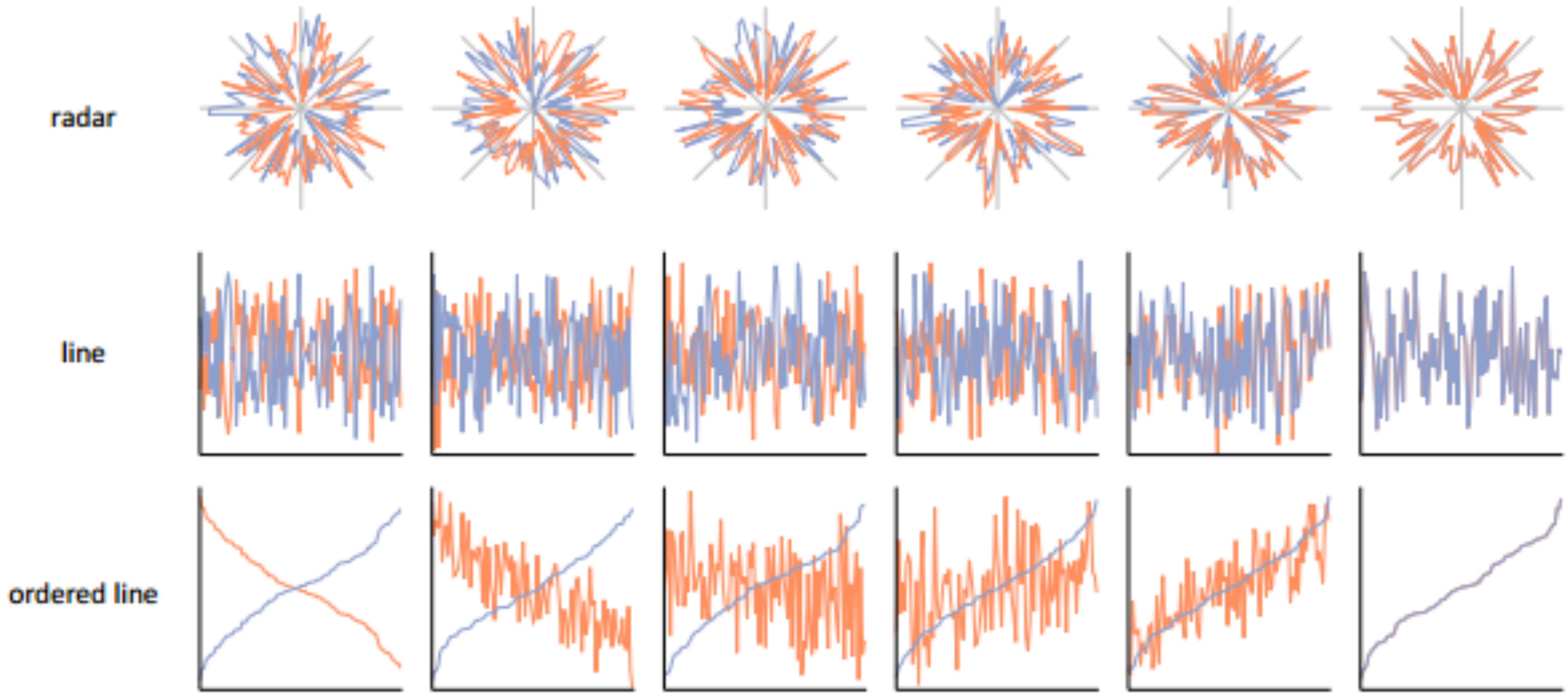


Harrison et al., TVCG 2014

Recap

- Consider how data behaves
    - Can you add? Subtract? Compare? Is there a smallest, or are values just different from one another? Etc.
- Consider how the basic visual channels behave, match the two appropriately

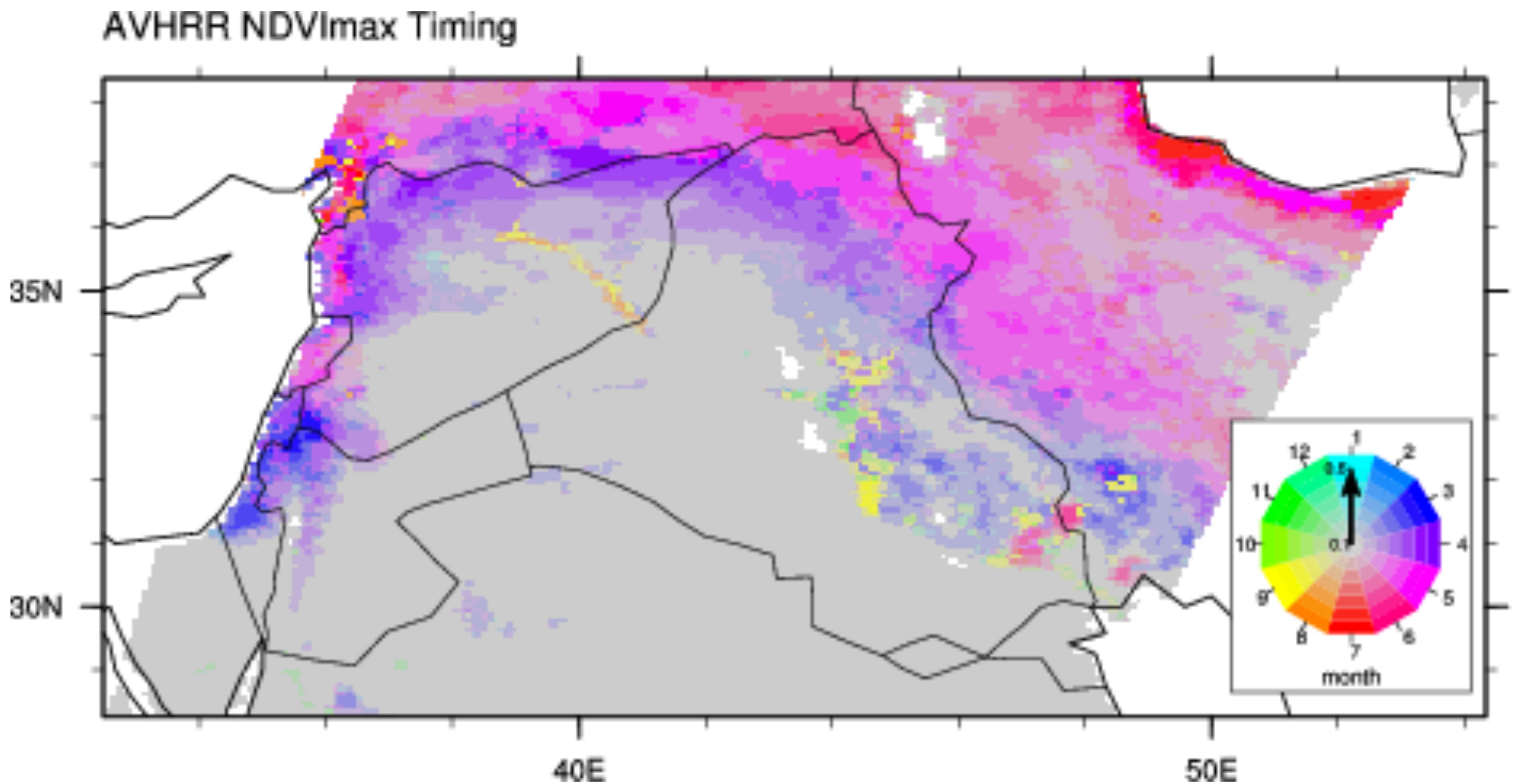
- Consider how the basic visual channels behave, match the two appropriately

What if they don’t match?

“WEIRD” DATA

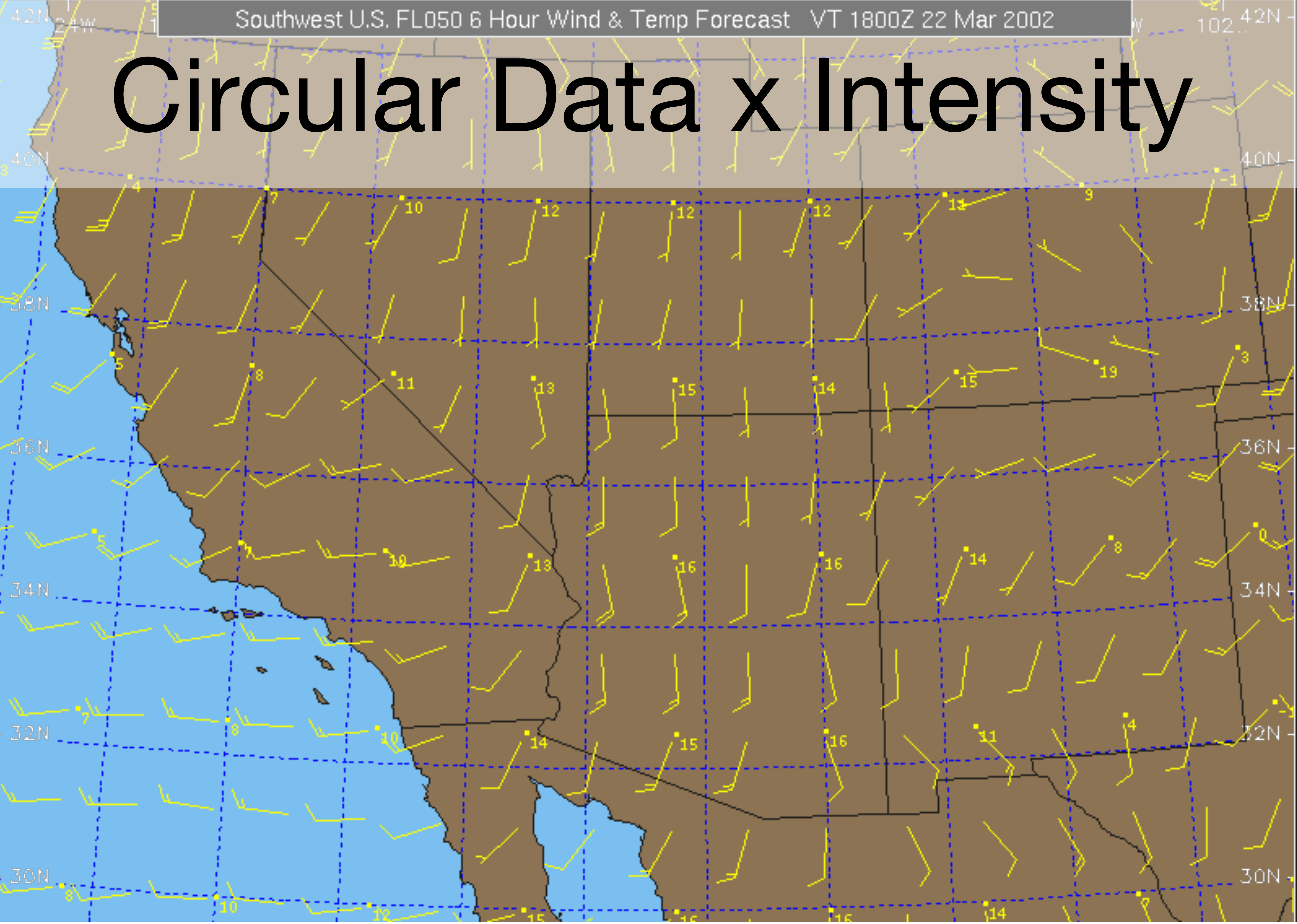
(A prelude to techniques)

Circular Data x Intensity



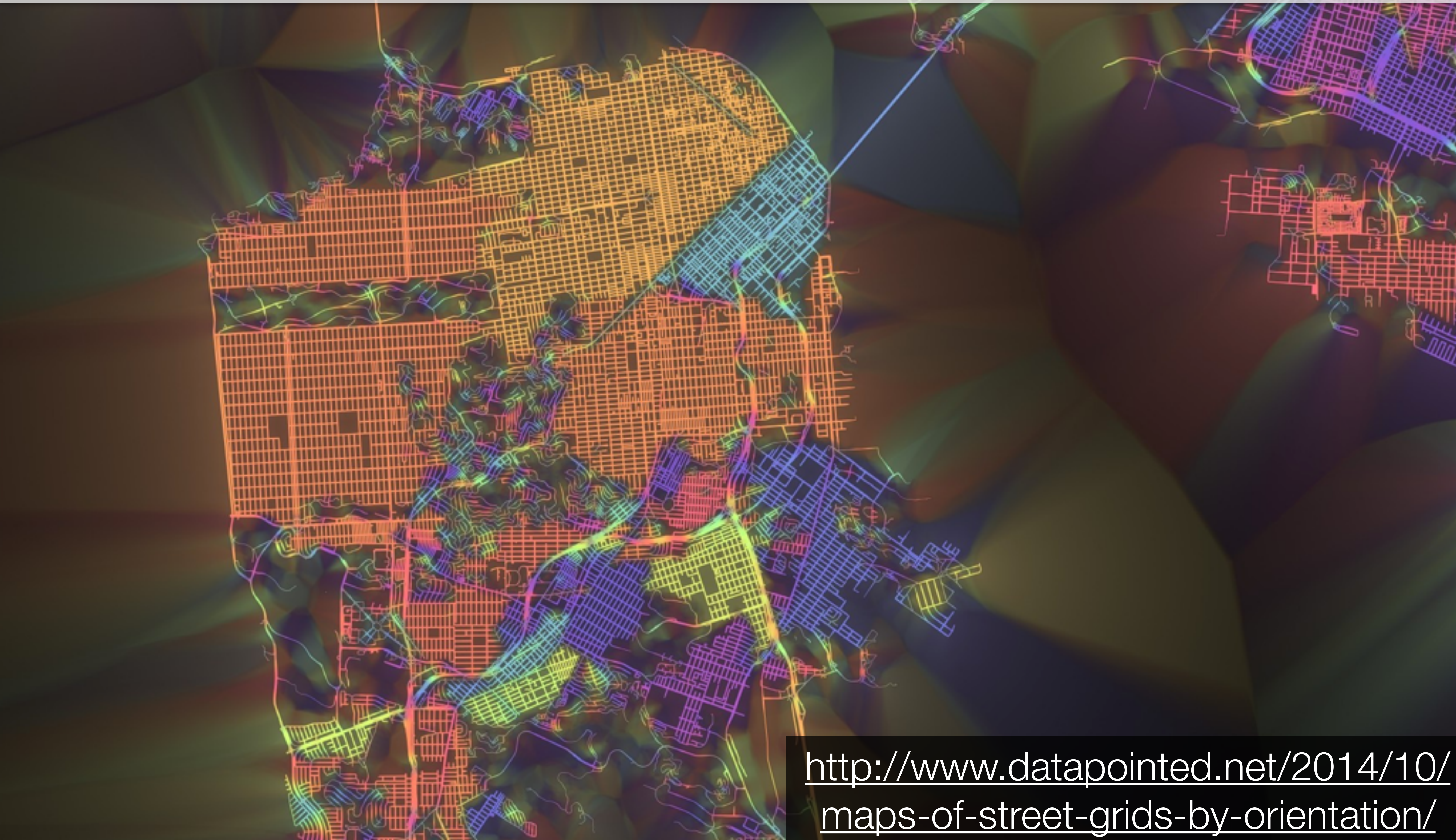
https://www.ncl.ucar.edu/Applications/evans.shtml

Circular Data x Intensity



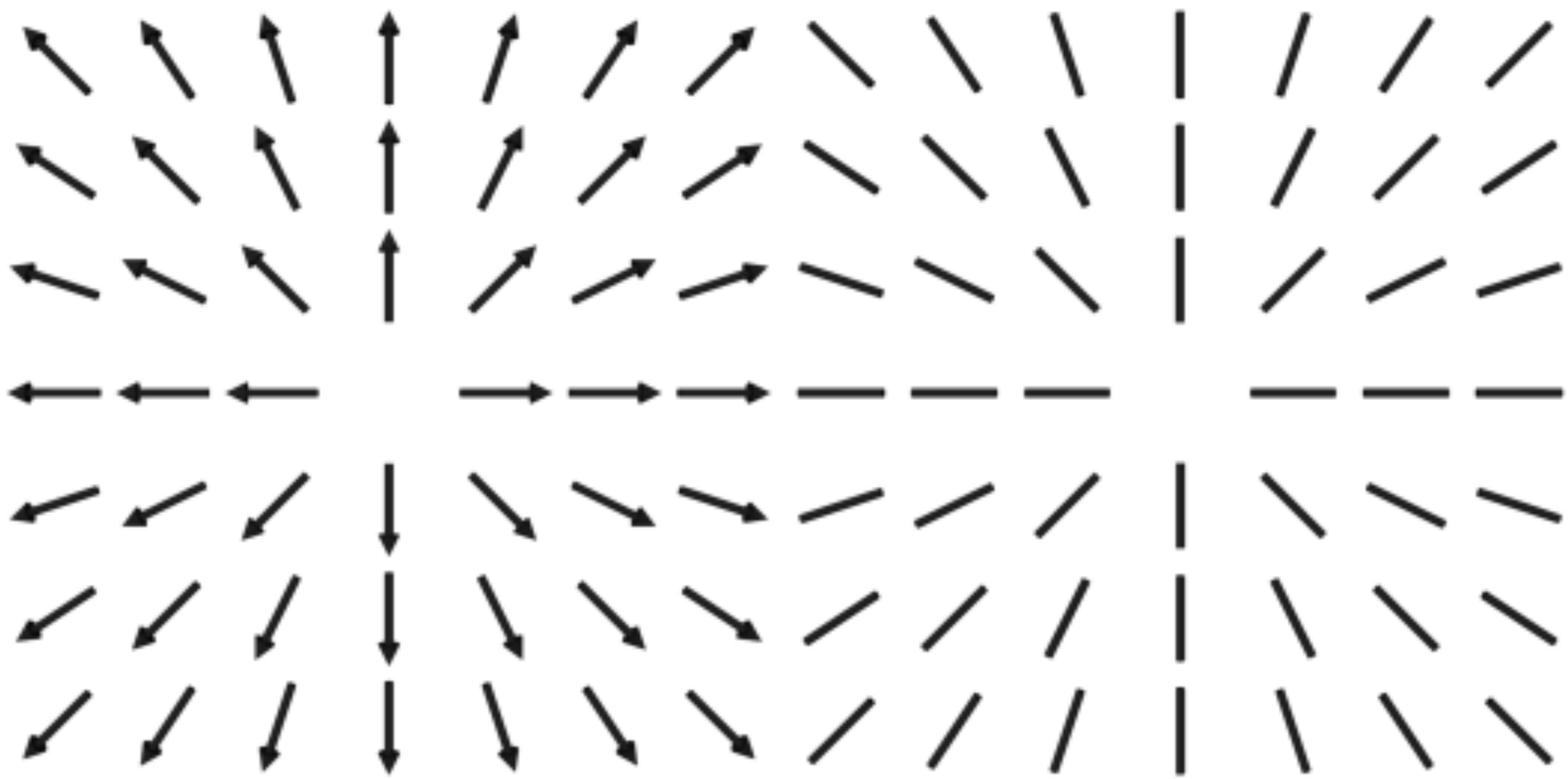
http://delta.jepptech.com/jifp/help/winds_and_temperatures_aloft.htm

Orientation vs. Direction



http://www.datapointed.net/2014/10/maps-of-street-grids-by-orientation/

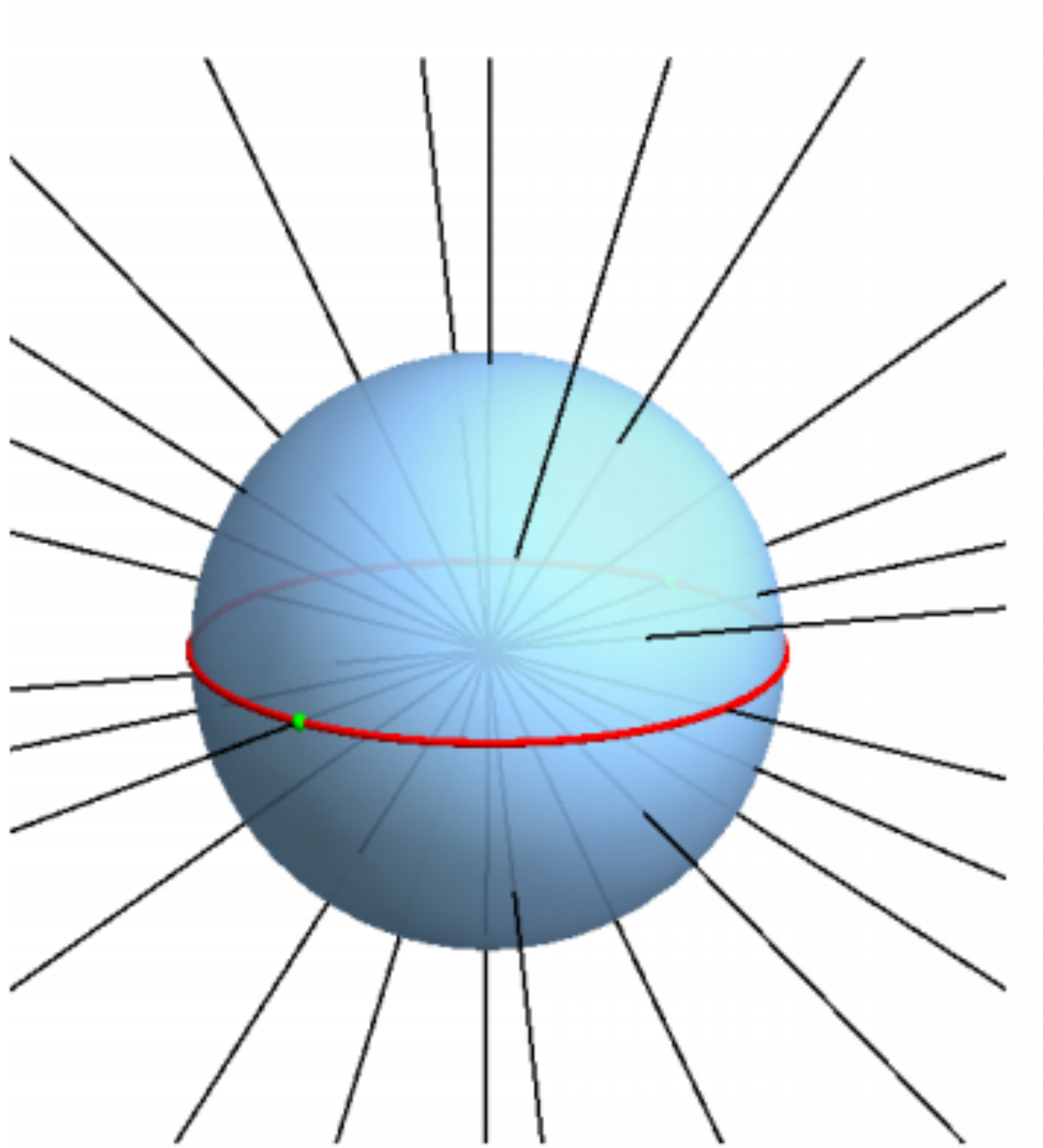
Orientation vs. Direction



(a) (b)

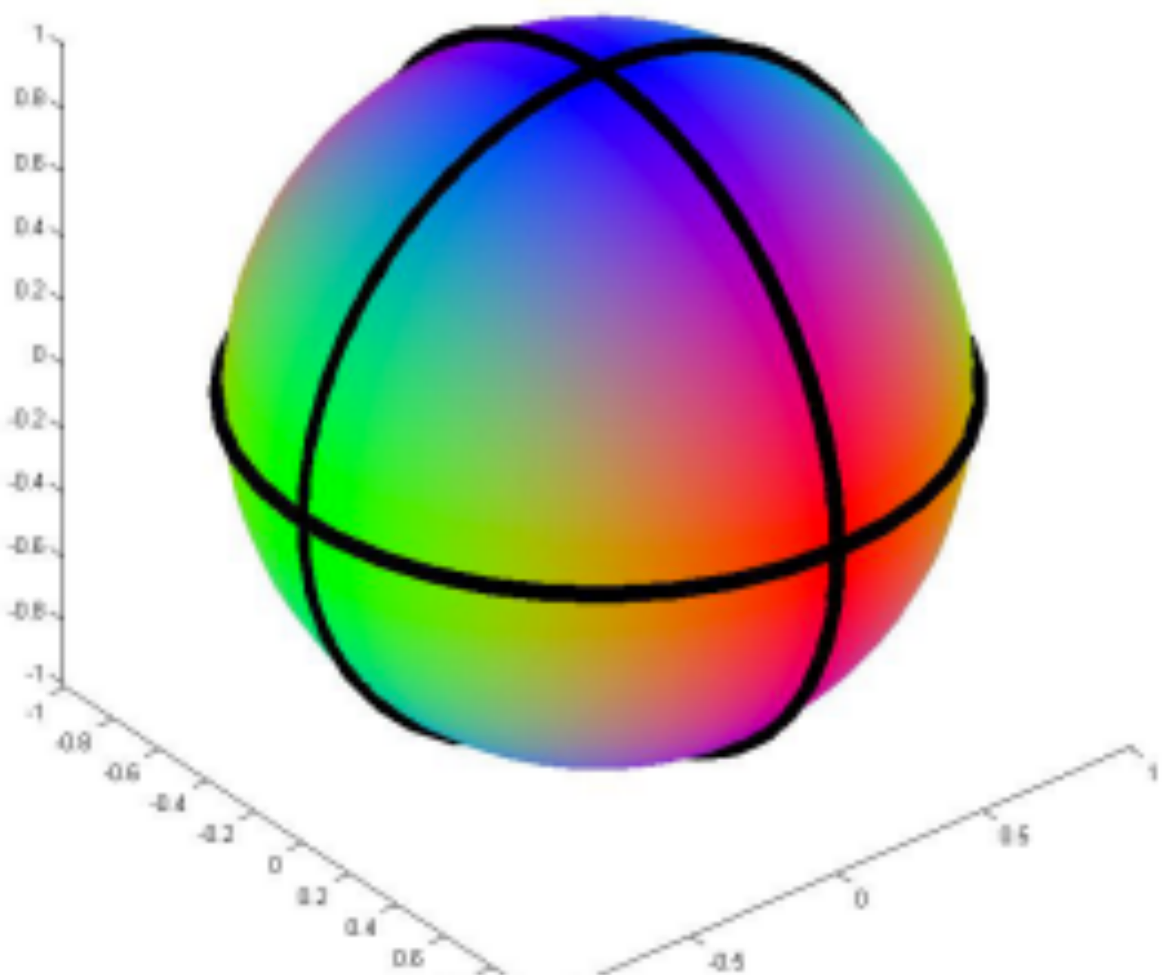
Demiralp et al. 2009

Orientation vs. Direction



Demiralp et al. 2009

Orientation vs. Direction



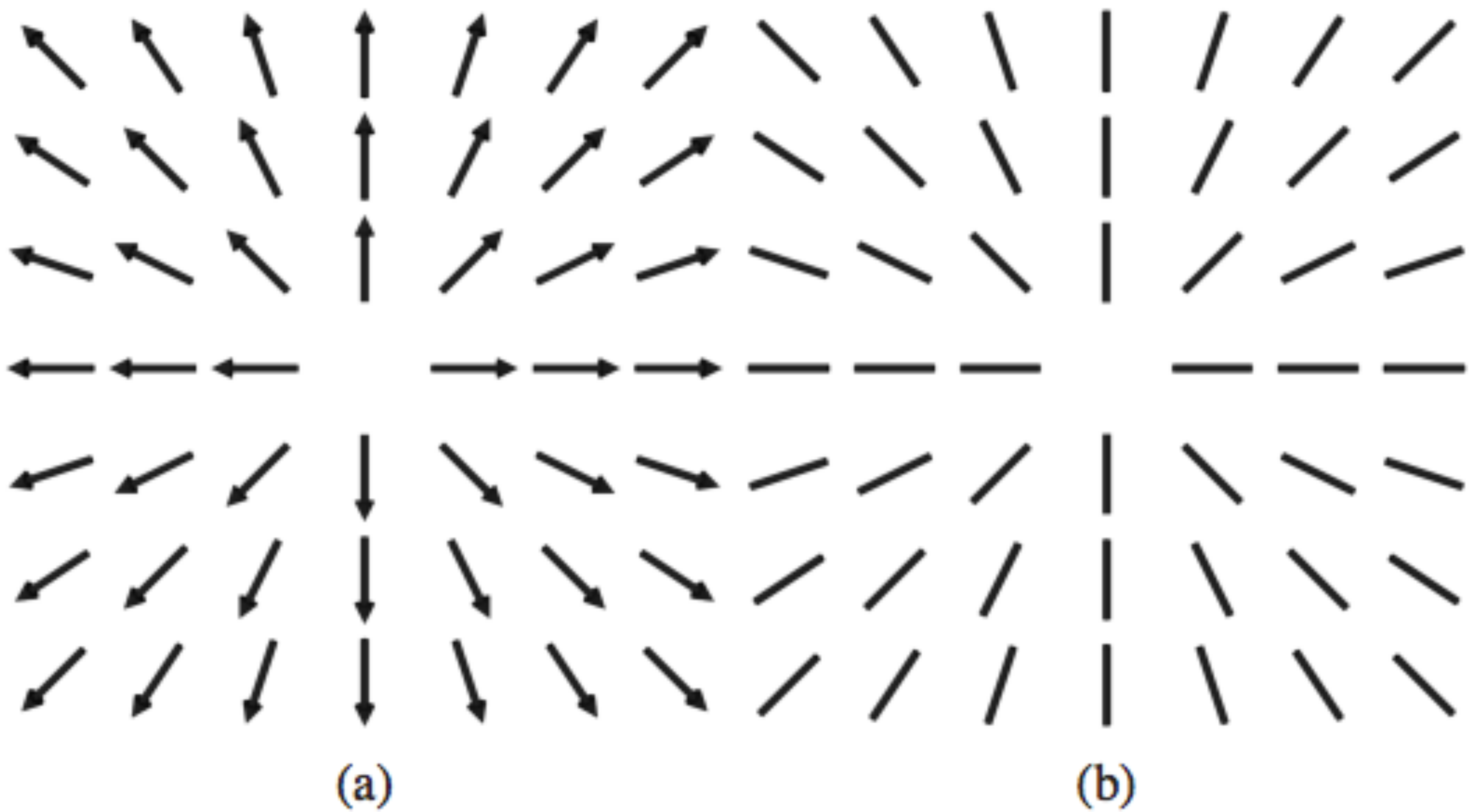
(c)

This is a bad colormap.

Why?

Demiralp et al. 2009

Orientation vs. Direction



Demiralp et al. 2009

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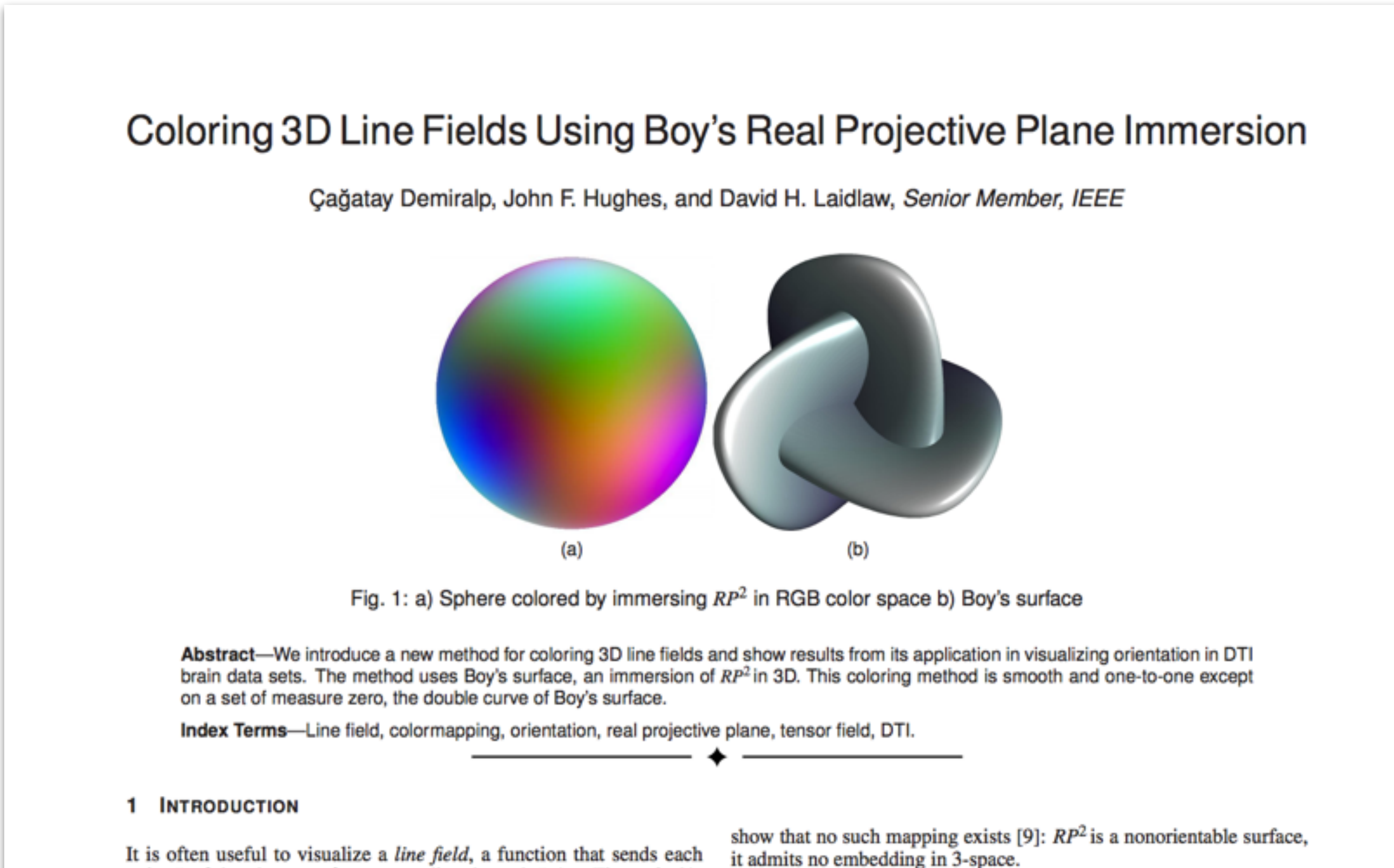


Coloring 3D Line Fields Using Boy's Real Projective Plane Immersion

Çağatay Demiralp, John F. Hughes, and David H. Laidlaw, *Senior Member, IEEE*

(a) (b)

Fig. 1: a) Sphere colored by immersing RP^2 in RGB color space b) Boy's surface

Abstract—We introduce a new method for coloring 3D line fields and show results from its application in visualizing orientation in DTI brain data sets. The method uses Boy's surface, an immersion of RP^2 in 3D. This coloring method is smooth and one-to-one except on a set of measure zero, the double curve of Boy's surface.

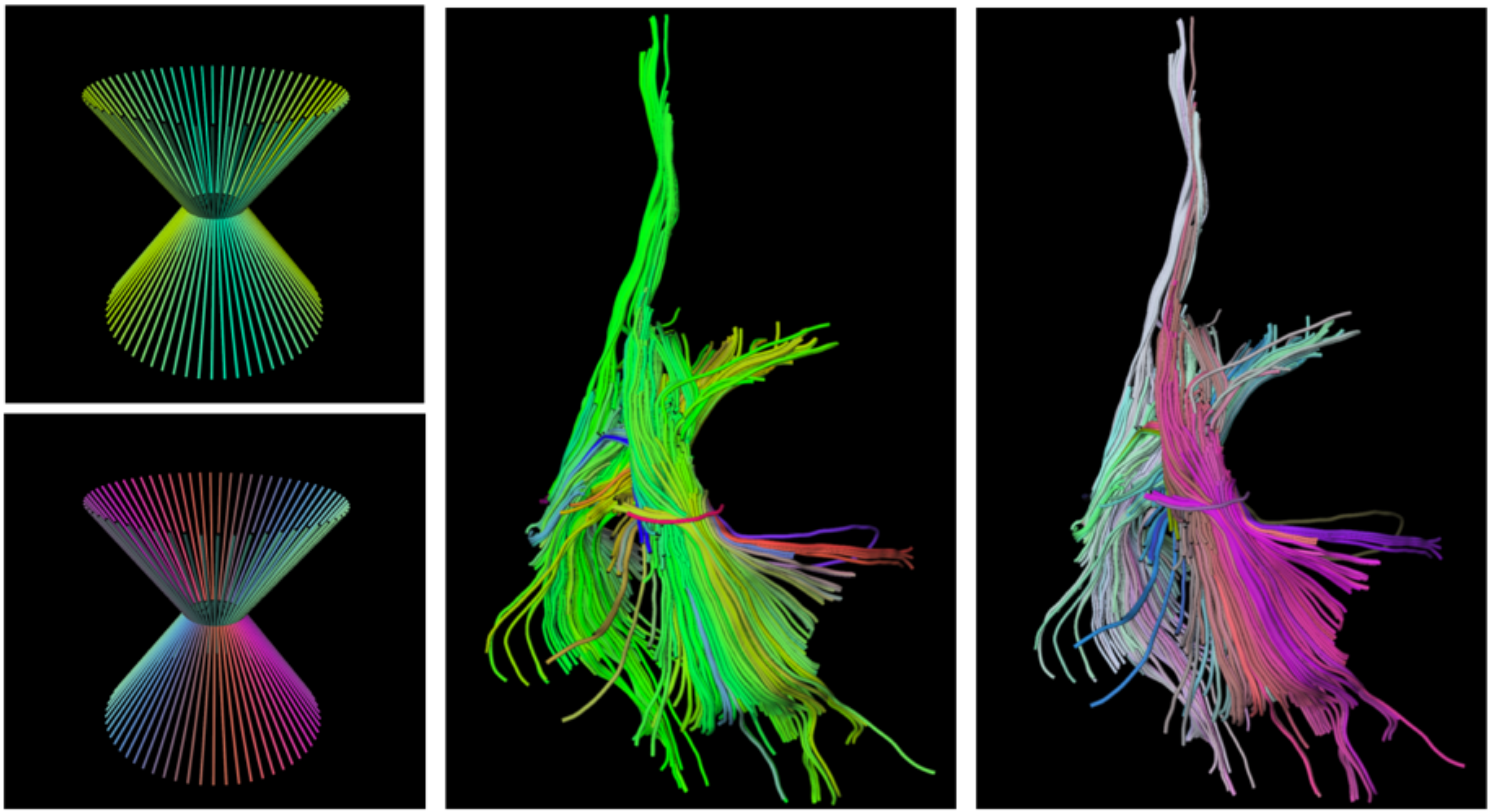
Index Terms—Line field, colormapping, orientation, real projective plane, tensor field, DTI.

1 Introduction

It is often useful to visualize a *line field*, a function that sends each

show that no such mapping exists [9]: RP^2 is a nonorientable surface, it admits no embedding in 3-space.

Orientation vs. Direction



(a) (b) (c)

Demiralp et al. 2009

Probability Distributions

- Map behavior of conditional distributions, marginal distributions, etc. to visual channels: Product Plots, Wickham and Hoffman, TVCG 2011

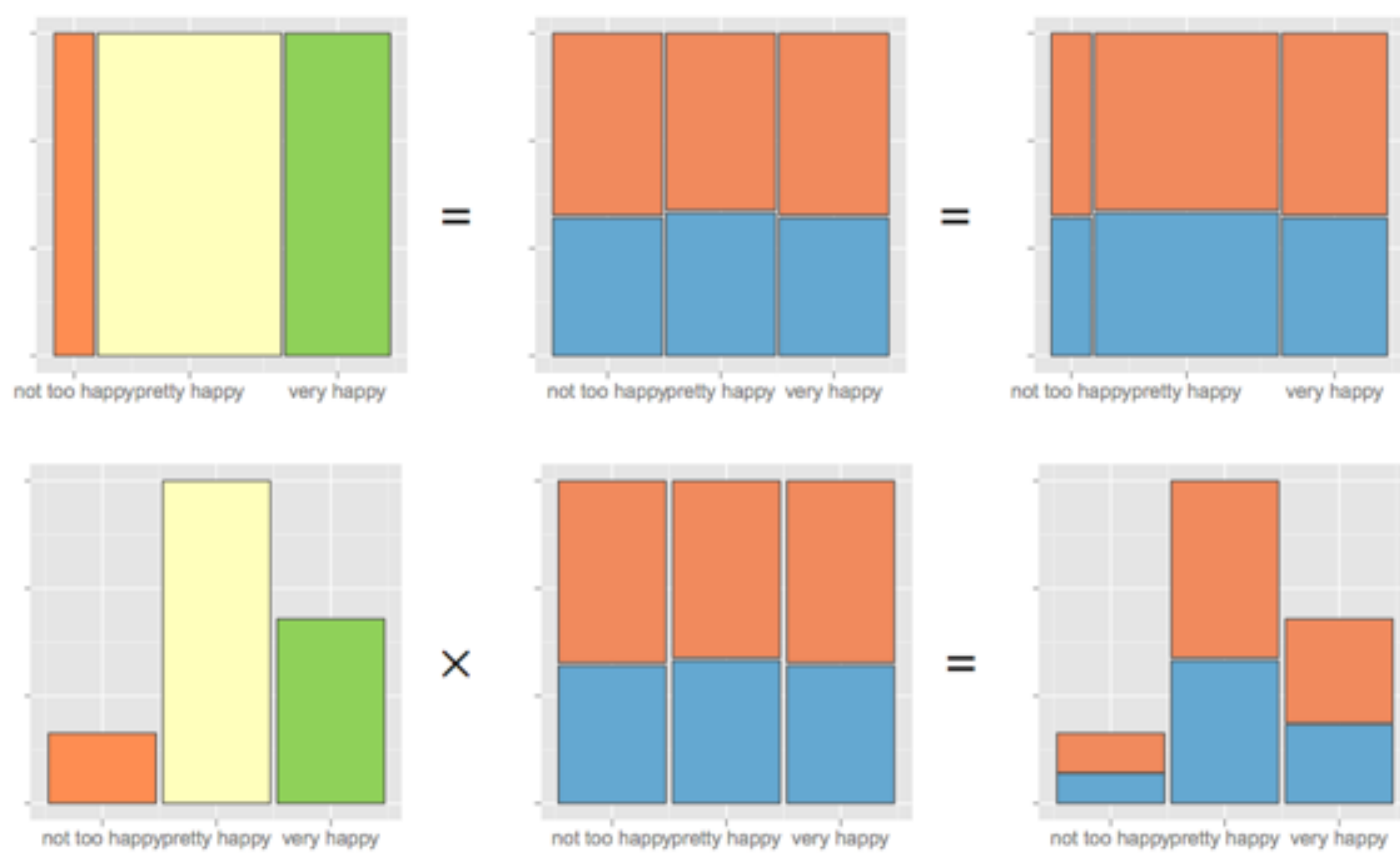


Fig. 5. Plots of the distribution of happiness and sex (■ male, ■ female) (Left) $f(happy)$, (Middle) $f(sex|happy)$, (Right) $f(happy, sex)$.