

# Decoding and Encoding Visualizations: Marks, Channels, and Color

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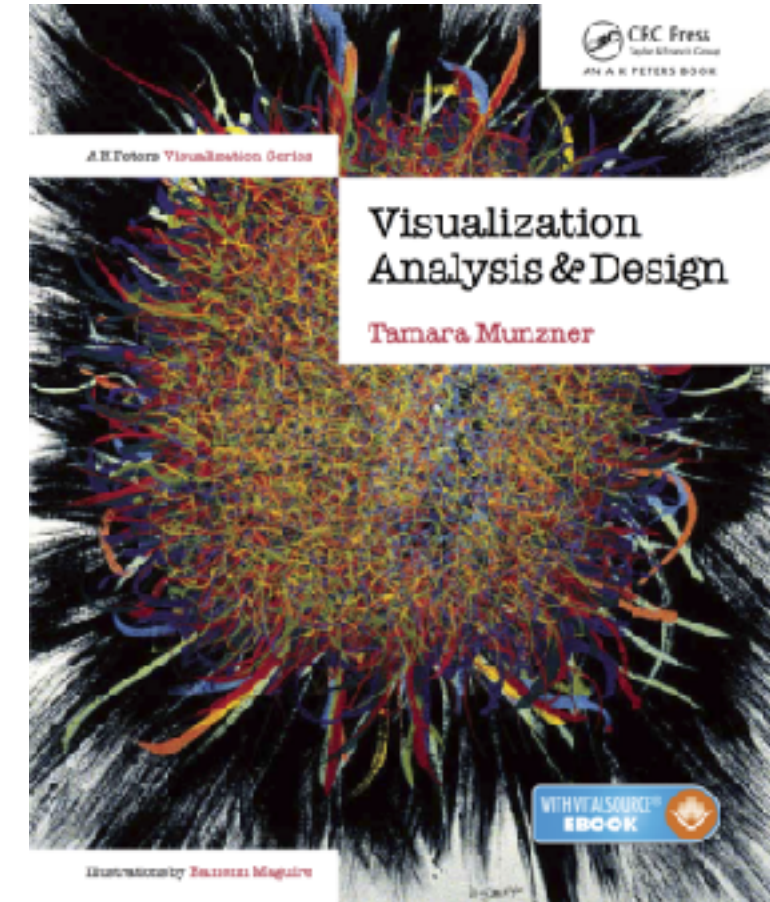
**VisualISE**

**(Visualization for Informal Science Education)  
Exploratorium, San Francisco CA, 8 May 2019**

**[www.cs.ubc.ca/~tmm/talks.html#visualise19](http://www.cs.ubc.ca/~tmm/talks.html#visualise19)**

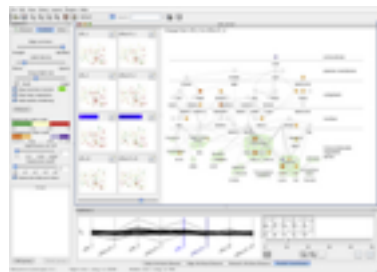


THE UNIVERSITY OF BRITISH COLUMBIA



**[@tamaramunzner](https://twitter.com/tamaramunzner)**

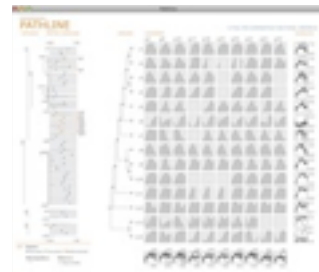
# How to decode a visualization? How to encode data visually?



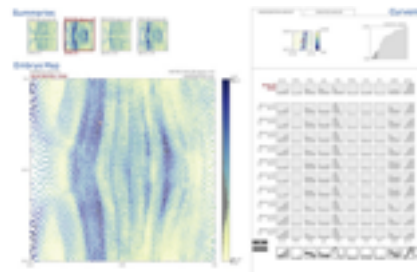
*Cerebral*  
genomics



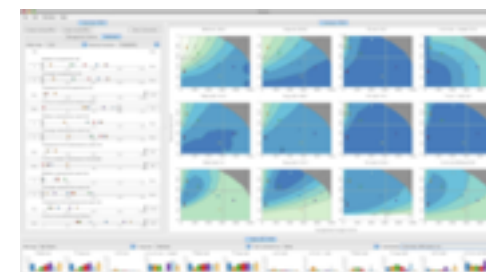
*MizBee*  
genomics



*Pathline*  
genomics



*MulteeSum*  
genomics



*Vismon*  
fisheries management



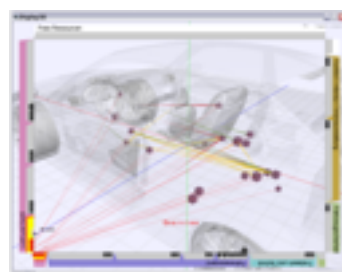
*QuestVis*  
sustainability



*WiKeVis*  
in-car networks



*MostVis*  
in-car networks



*Car-X-Ray*  
in-car networks



*ProgSpy2010*  
in-car networks



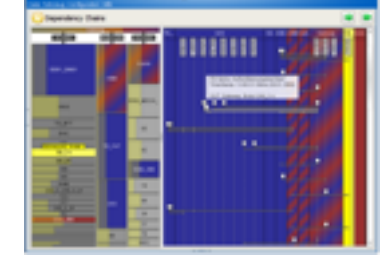
*RelEx*  
in-car networks



*Cardiogram*  
in-car networks



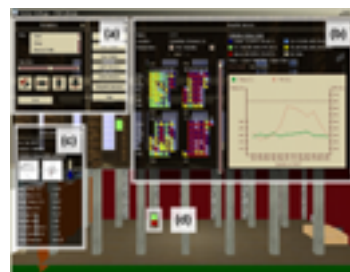
*AutobahnVis*  
in-car networks



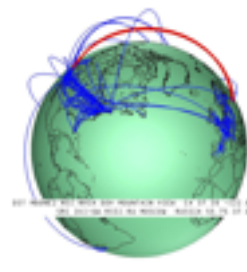
*VisTra*  
in-car networks



*Constellation*  
linguistics



*LibVis*  
cultural heritage



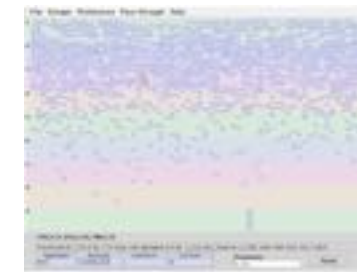
*Caidants*  
multicast



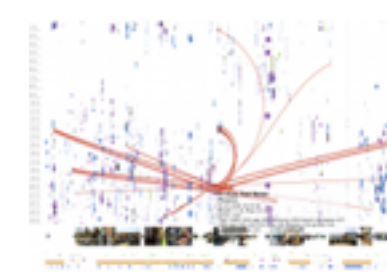
*SessionViewer*  
web log analysis



*LiveRAC*  
server hosting



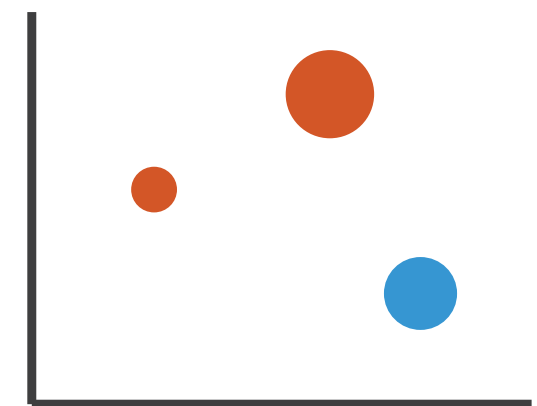
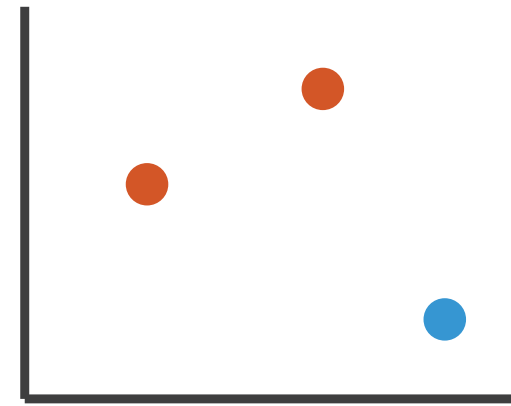
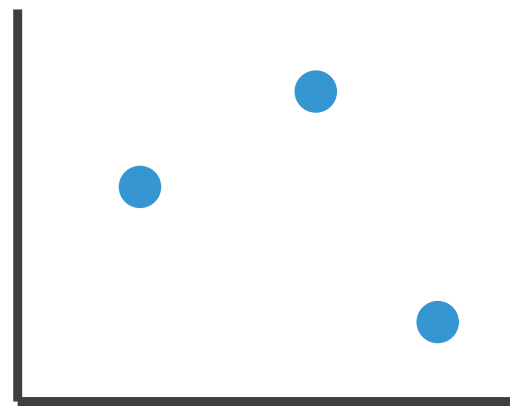
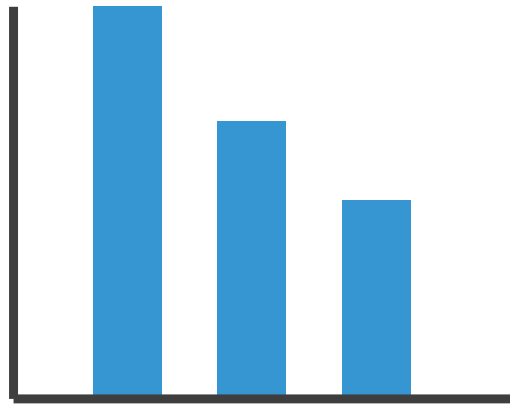
*PowerSetViewer*  
data mining



*LastHistory*  
music listening

# Decoding and encoding visual representations

- systematic way to analyze structure



# Decoding and encoding: Marks and channels

- marks

  - geometric primitives

→ Points



→ Lines



→ Areas



- channels

  - control appearance of marks

→ Position

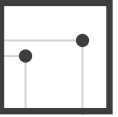
→ Horizontal



→ Vertical



→ Both



→ Color



→ Shape



→ Tilt



→ Size

→ Length



→ Area

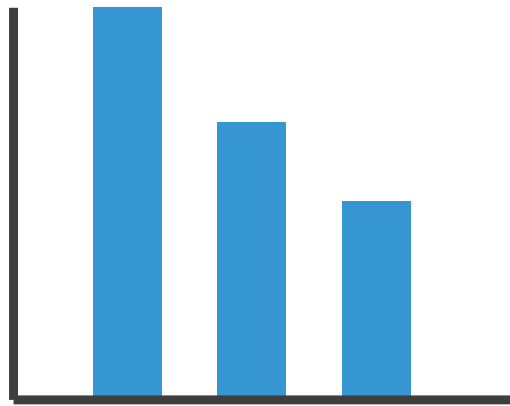


→ Volume



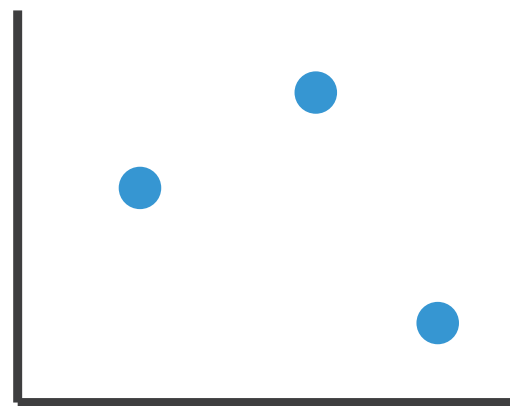
# Decoding and encoding visual representations

- systematic way to analyze structure
  - as combination of marks and channels



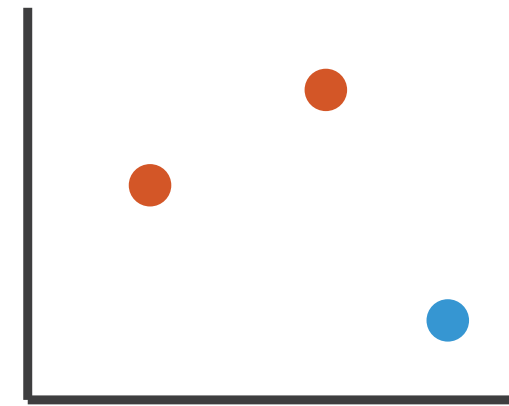
1:  
vertical position

mark: line



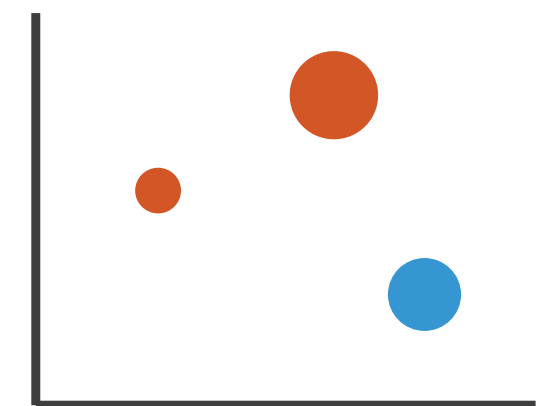
2:  
vertical position  
horizontal position

mark: point



3:  
vertical position  
horizontal position  
color hue

mark: point



4:  
vertical position  
horizontal position  
color hue  
size (area)

mark: point

# How to choose?

- characteristics of...
  - data
  - task
  - human perceptual system

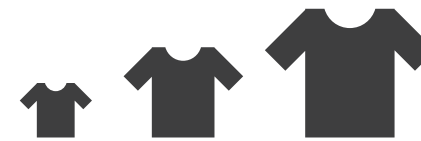
## ➔ Attribute Types

➔ Categorical

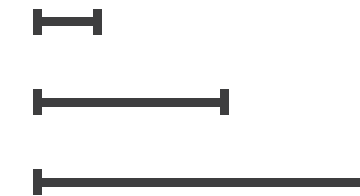


➔ Ordered

➔ *Ordinal*



➔ *Quantitative*



## ➔ Ordering Direction

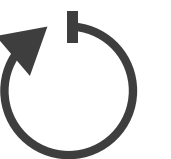
➔ Sequential



➔ Diverging



➔ Cyclic



# Channels

Position on common scale



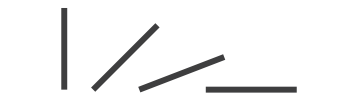
Position on unaligned scale



Length (1D size)



Tilt/angle



Area (2D size)



Depth (3D position)



Color luminance



Color saturation



Curvature



Volume (3D size)



Spatial region



Color hue



Motion



Shape



# Channels

## ➔ Magnitude Channels: Ordered Attributes

Position on common scale 

Position on unaligned scale 

Length (1D size) 


Tilt/angle 

Area (2D size) 

Depth (3D position) 

Color luminance 

Color saturation 

Curvature 

Volume (3D size) 

Same  
Same

## ➔ Identity Channels: Categorical Attributes

Spatial region 

Color hue 

Motion 

Shape 

- **expressiveness**
  - match channel and data characteristics



# Channels

## ➔ Magnitude Channels: Ordered Attributes

Position on common scale



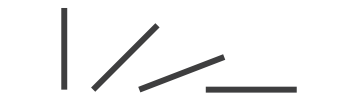
Position on unaligned scale



Length (1D size)



Tilt/angle



Area (2D size)



Depth (3D position)



Color luminance



Color saturation



Curvature



Volume (3D size)



Best

Effectiveness

Least

Same

Same

## ➔ Identity Channels: Categorical Attributes

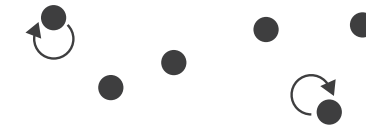
Spatial region



Color hue



Motion



Shape



- **expressiveness**

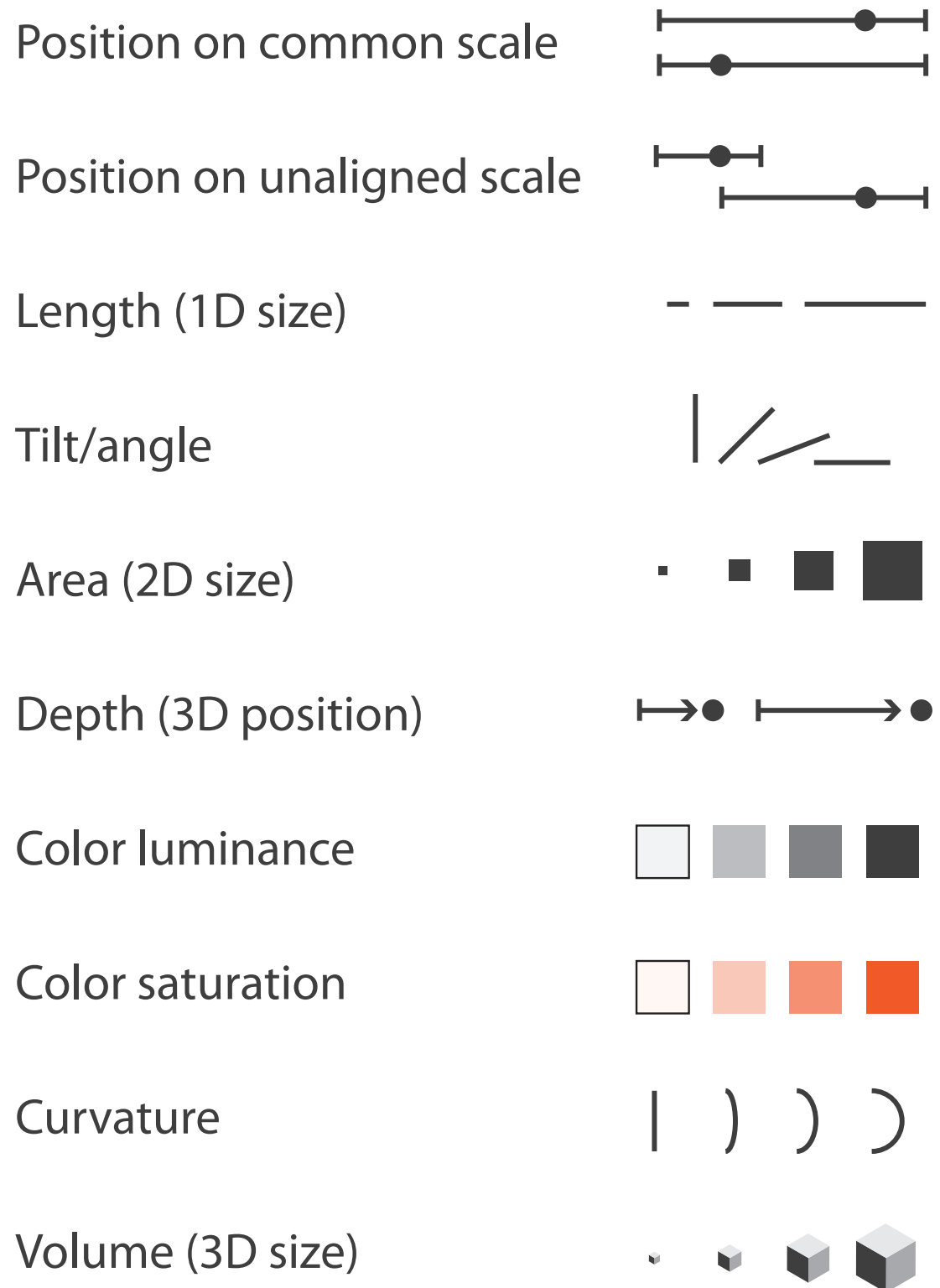
- match channel and data characteristics

- **effectiveness**

- channels differ in accuracy of perception

# Channels

## ➔ Magnitude Channels: Ordered Attributes



## ➔ Identity Channels: Categorical Attributes



Best

Effectiveness

Least

Same

Same

- **expressiveness**
  - match channel and data characteristics
- **effectiveness**
  - channels differ in accuracy of perception
- **distinguishability**
  - match available levels in channel w/ data

# How?

## Encode

### → Arrange

→ Express



→ Separate



→ Order



→ Align



→ Use



### → Map

from **categorical** and **ordered** attributes

→ Color

→ Hue



→ Saturation



→ Luminance



→ Size, Angle, Curvature, ...



→ Shape



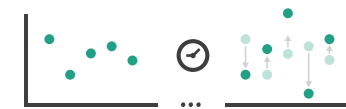
→ Motion

*Direction, Rate, Frequency, ...*

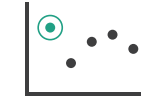


## Manipulate

### → Change



### → Select



### → Navigate

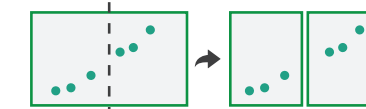


## Facet

### → Juxtapose



### → Partition



### → Superimpose



## Reduce

### → Filter



### → Aggregate



### → Embed

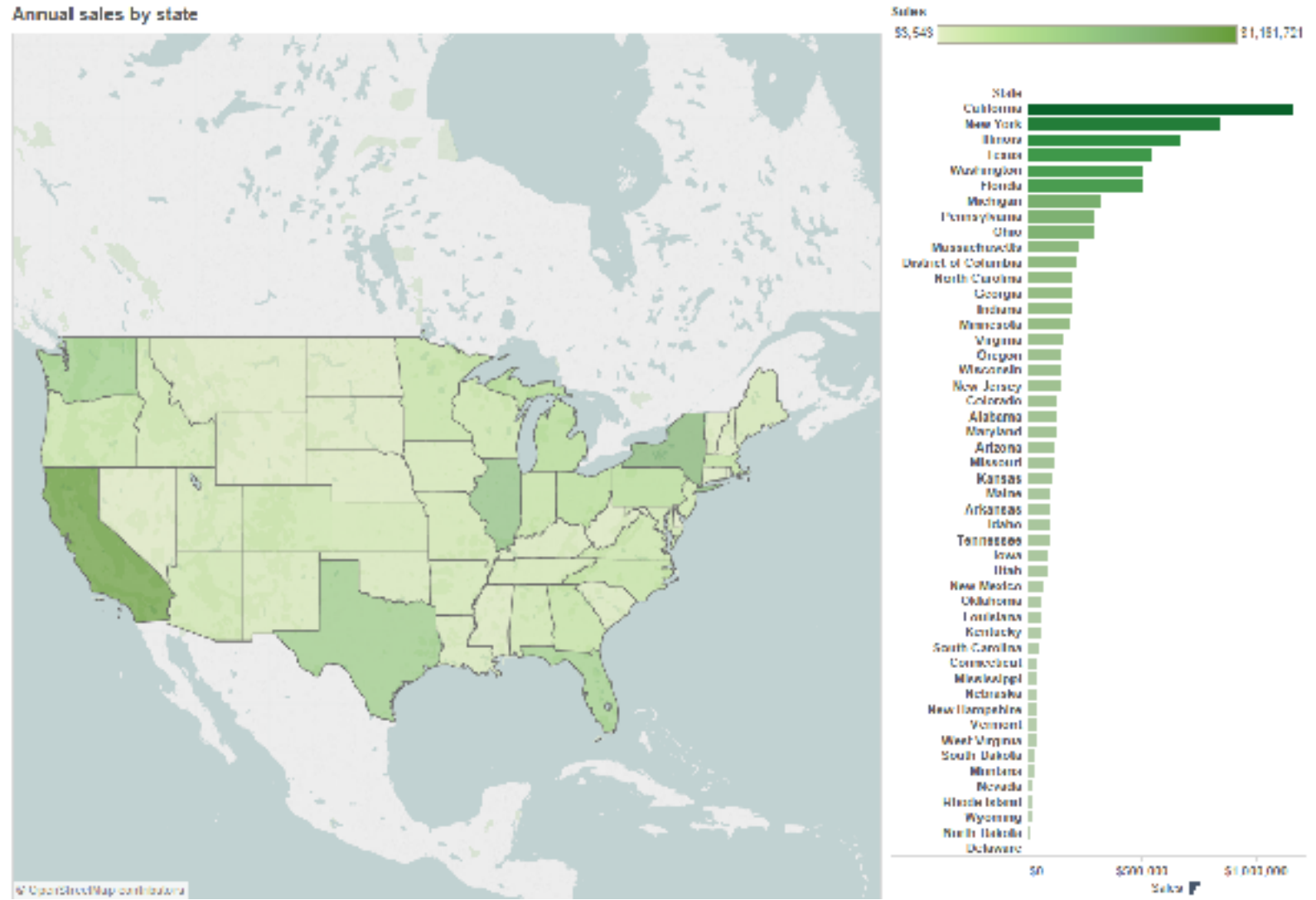
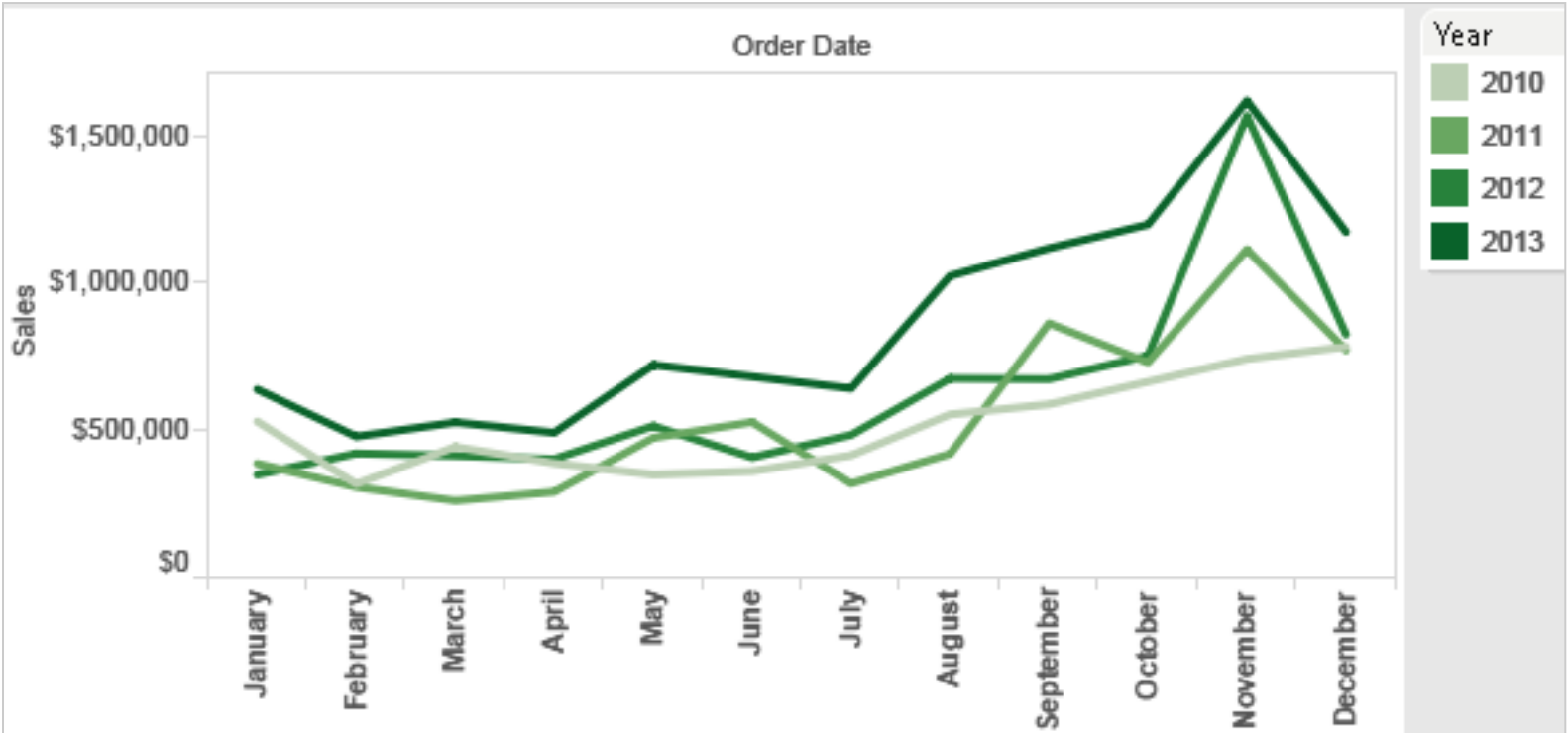
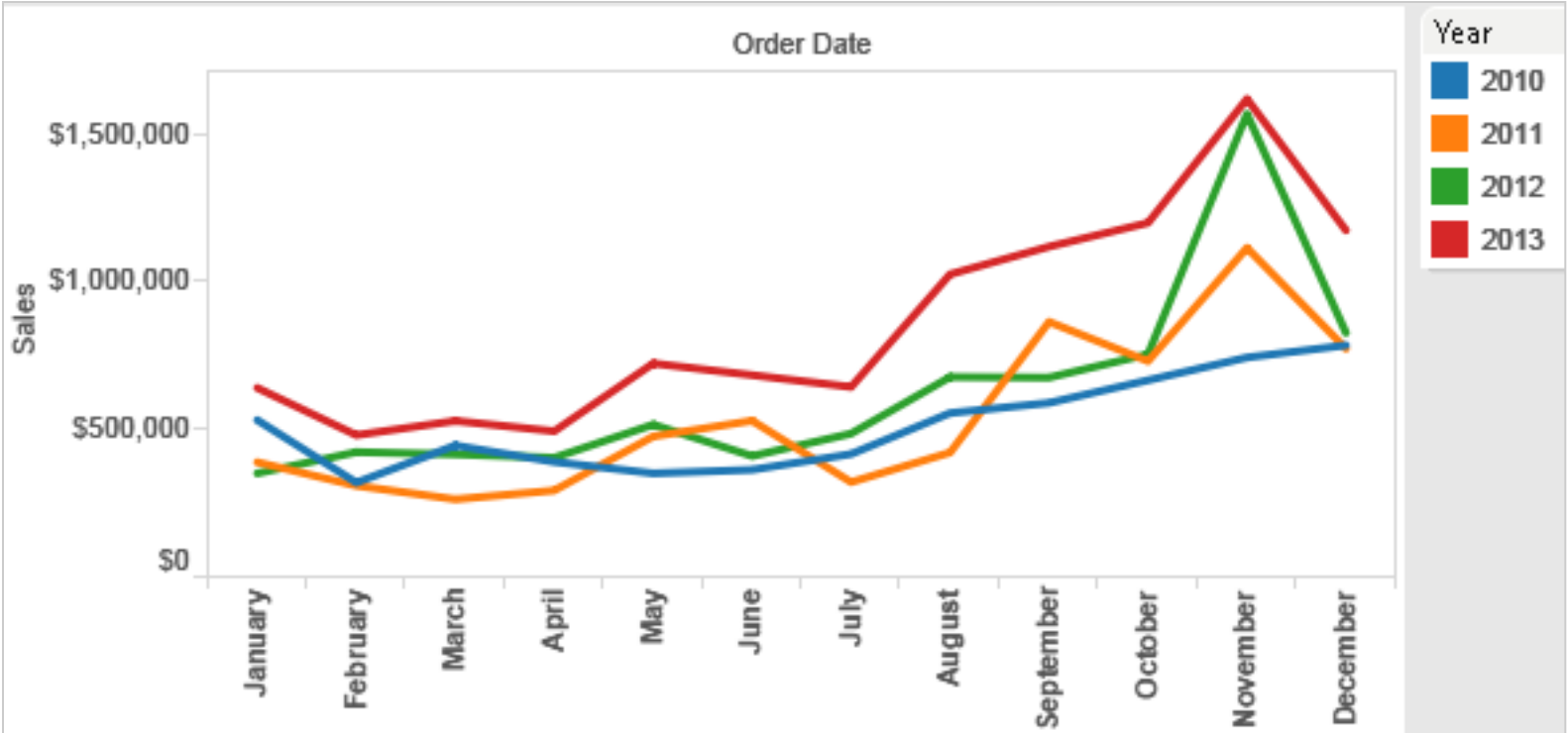


What?

Why?

How?

# Categorical vs ordered color



[Seriously Colorful: Advanced Color Principles & Practices. Stone.Tableau Customer Conference 2014.]

# Decomposing color

- first rule of color: do not talk about color!

- color is confusing if treated as monolithic

- decompose into three channels

- ordered can show magnitude

- luminance: how bright

- saturation: how colorful

- categorical can show identity

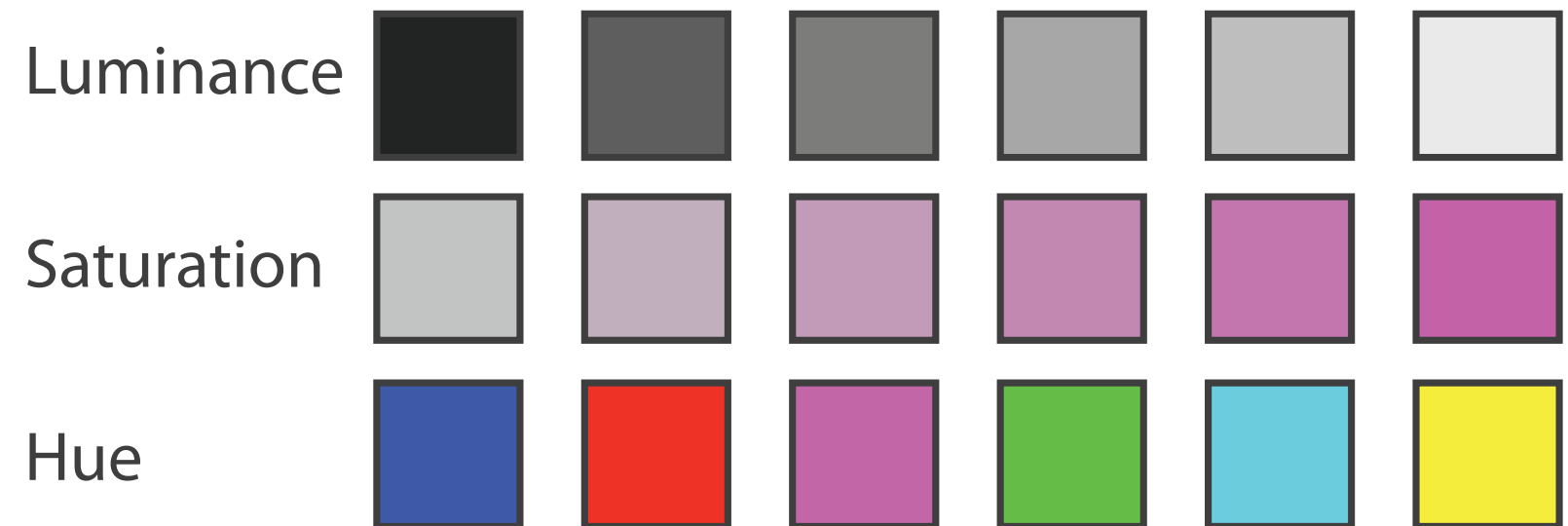
- hue: what color

- caveat: not well supported by current tools

- channels have different properties

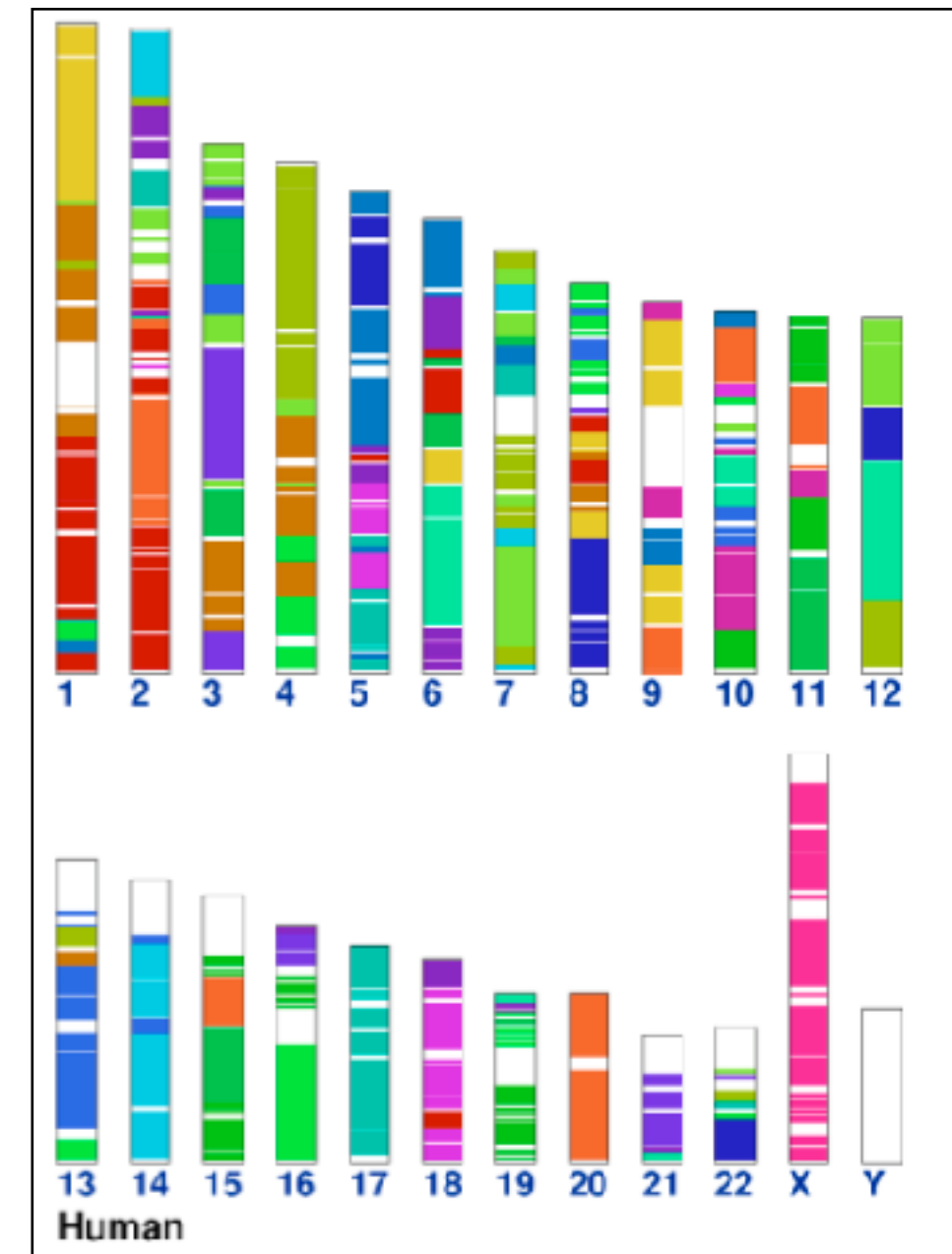
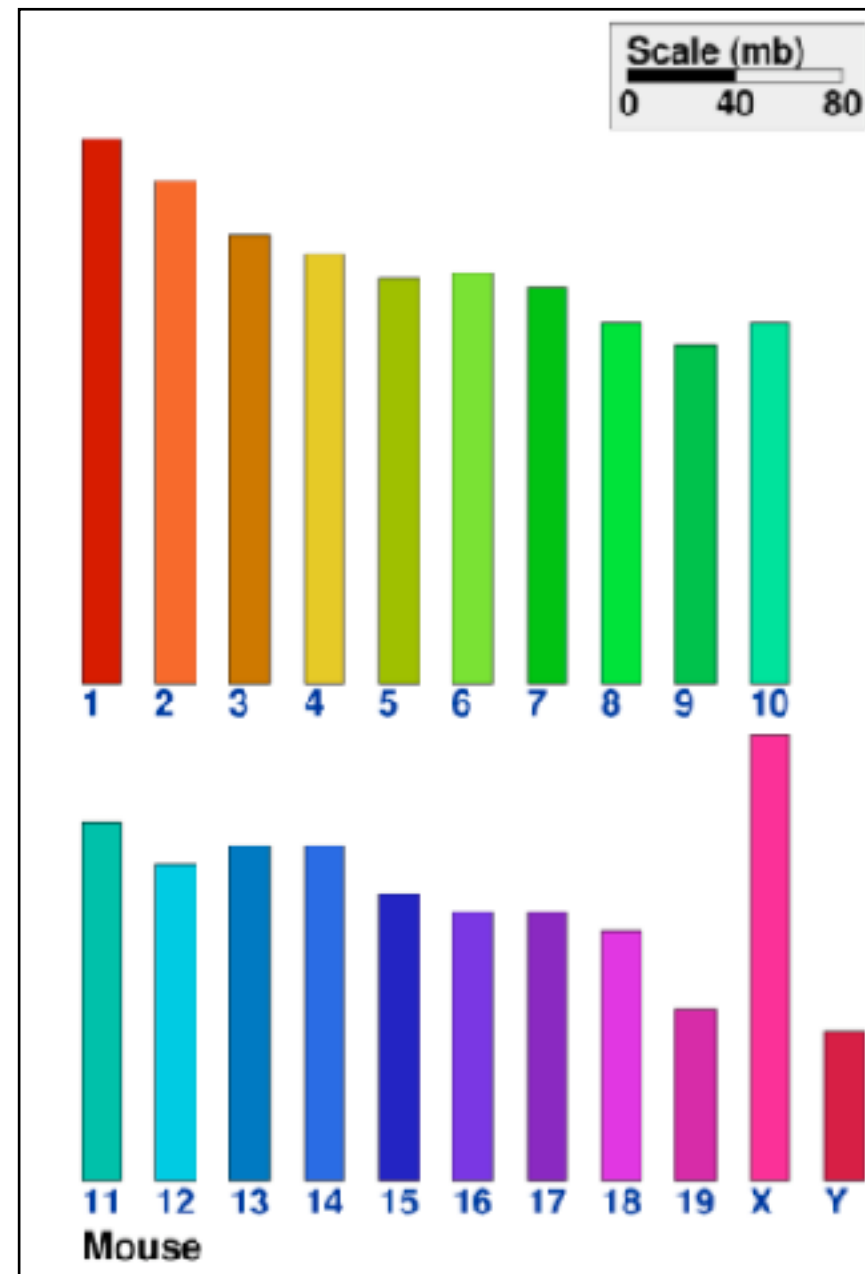
- what they convey directly to perceptual system

- how much they can convey: how many discriminable bins can we use?



# Categorical color: limited number of discriminable bins

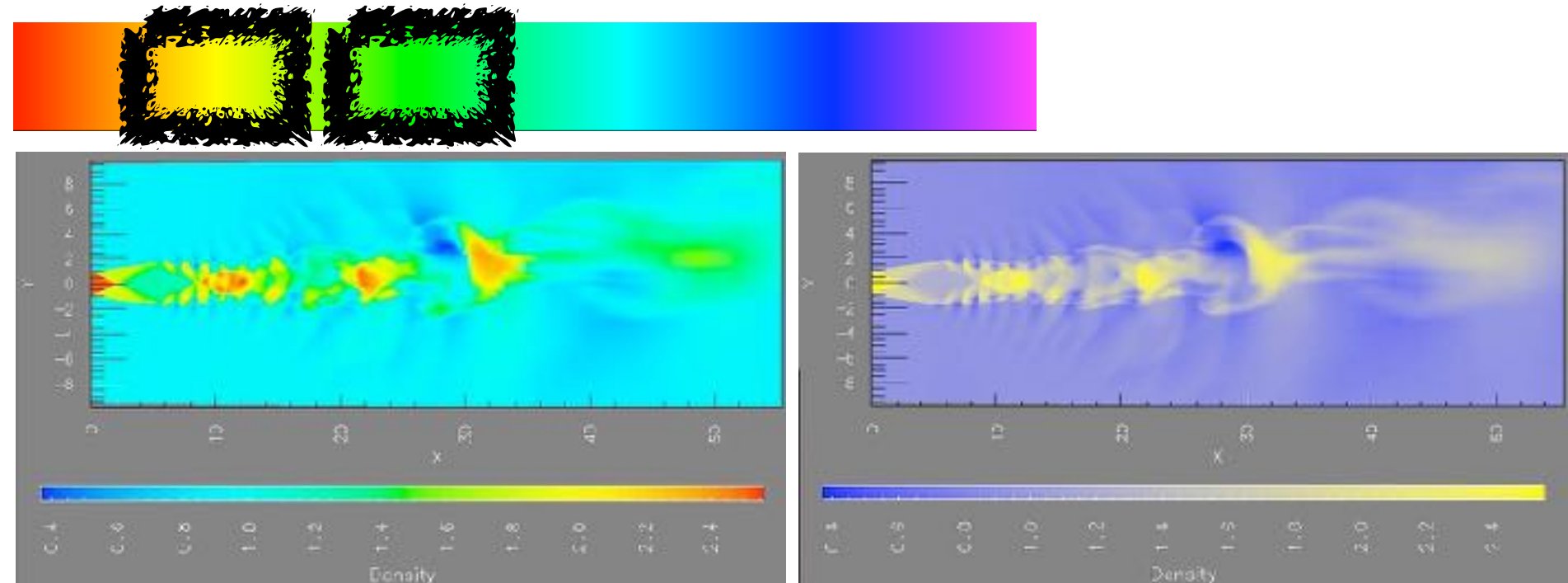
- human perception built on relative comparisons
  - great if color contiguous
  - surprisingly bad for absolute comparisons
- noncontiguous small regions of color
  - fewer bins than you want
  - rule of thumb: 6-12 bins, including background and highlights
- alternatives? other talks!



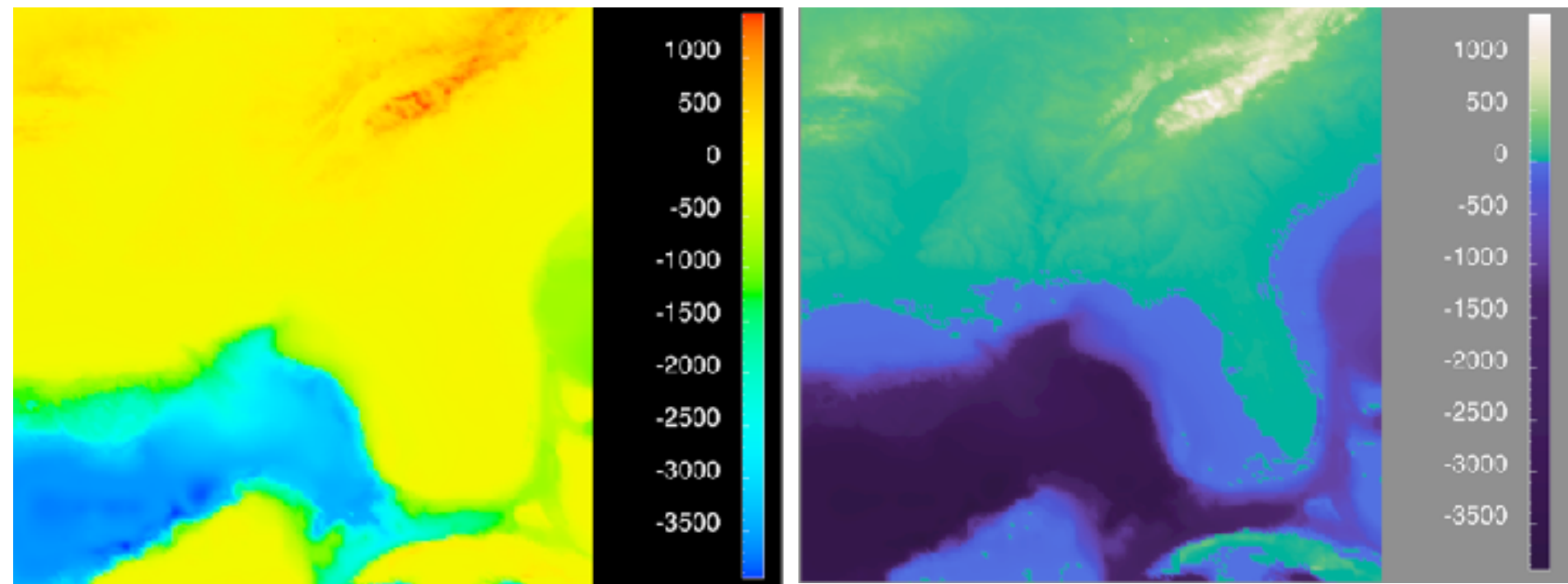
[Cinteny: flexible analysis and visualization of synteny and genome rearrangements in multiple organisms. Sinha and Meller. BMC Bioinformatics, 8:82, 2007.]

# Ordered color: Rainbow is poor default

- problems
  - perceptually unordered
  - perceptually nonlinear
- benefits
  - small-scale structure: see & name
- alternatives
  - large-scale structure: fewer hues
  - known structure: segmented
  - have it both ways, small+large:
    - multiple hues
    - monotonically increasing luminance



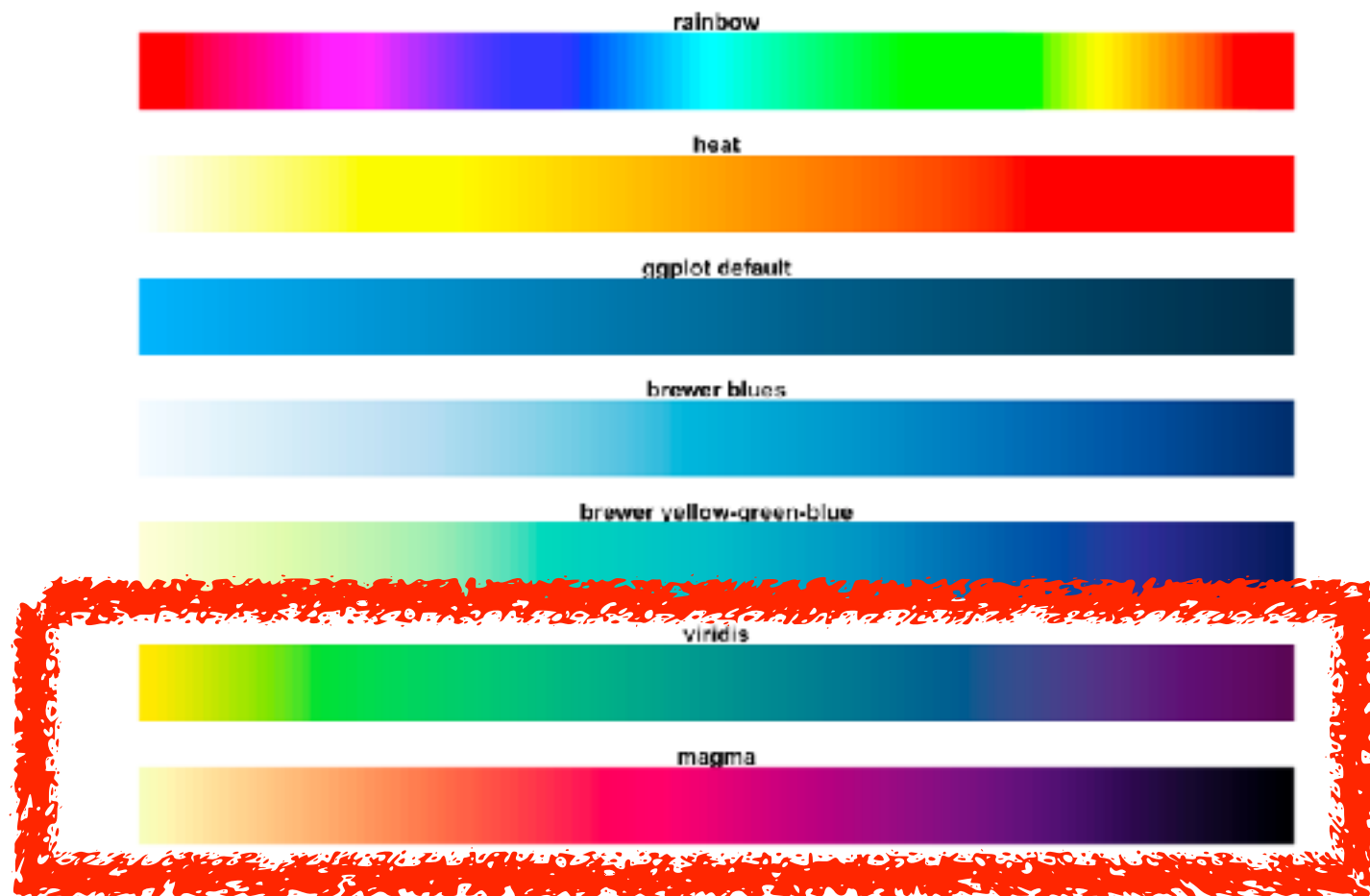
[A Rule-based Tool for Assisting Colormap Selection. Bergman, Rogowitz, and Treinish. Proc. IEEE Visualization (Vis), pp. 118–125, 1995.]



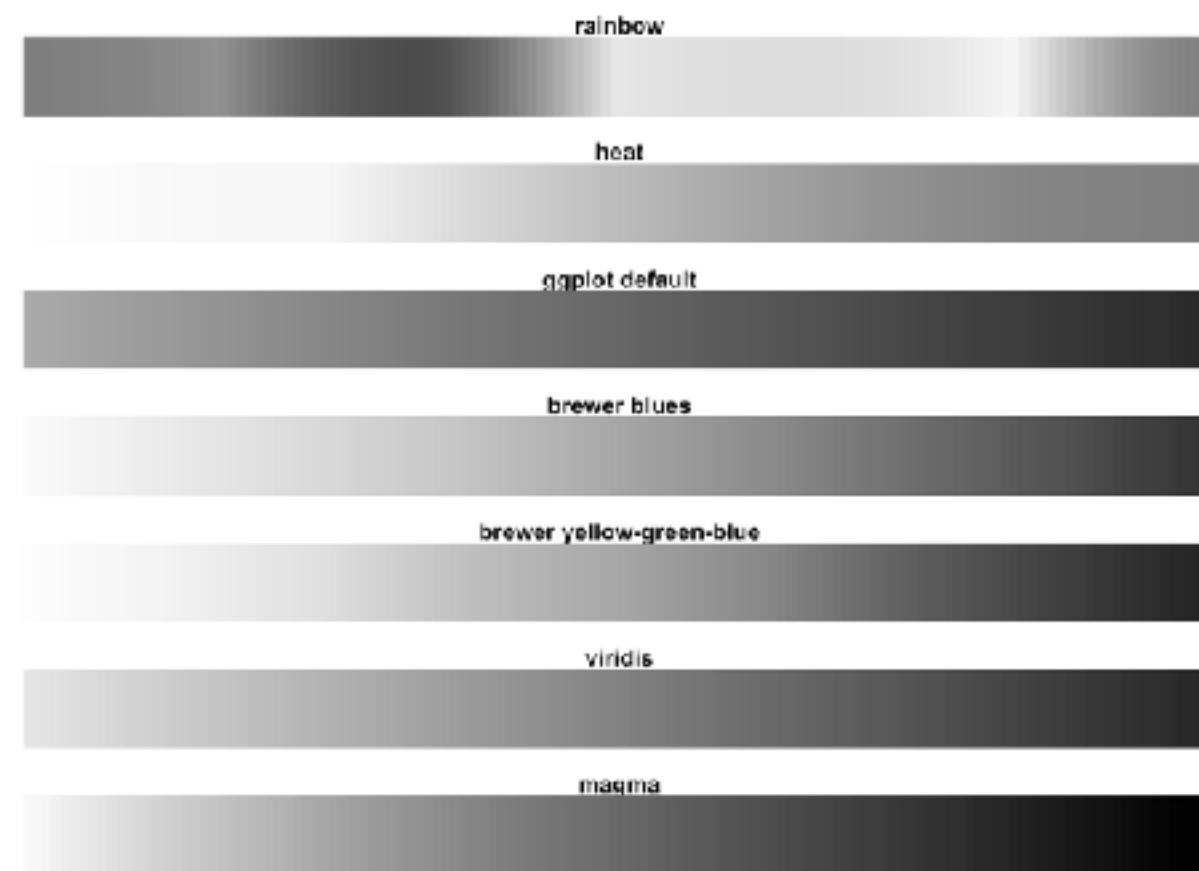
[Why Should Engineers Be Worried About Color? Treinish and Rogowitz 1998. <http://www.research.ibm.com/people/llloyd/color/color.HTM>]

# Viridis / Magma

- colorful, perceptually uniform, colorblind-safe, monotonically increasing luminance



<https://cran.r-project.org/web/packages/viridis/vignettes/intro-to-viridis.html>





# Further reading

- Visualization Analysis and Design. Munzner. AK Peters Visualization Series, CRC Press, 2014  
– *Chap 10: Map Color and Other Channels*
- ColorBrewer, Brewer.  
– <http://www.colorbrewer2.org>
- *Color In Information Display*. Stone. IEEE Vis Course Notes, 2006.  
– <http://www.stonesc.com/Vis06>
- A Field Guide to Digital Color. Stone. AK Peters, 2003.
- *Rainbow Color Map (Still) Considered Harmful*. Borland and Taylor. IEEE Computer Graphics and Applications 27:2 (2007), 14–17.
- Visual Thinking for Design. Ware. Morgan Kaufmann, 2008.
- Information Visualization: Perception for Design, 3rd edition. Ware. Morgan Kaufmann / Academic Press, 2004.
- <https://cran.r-project.org/web/packages/viridis/vignettes/intro-to-viridis.html>

# More Information

[@tamaramunzner](https://twitter.com/tamaramunzner)

- papers, videos, software, talks, courses

<http://www.cs.ubc.ca/group/infovis>

<http://www.cs.ubc.ca/~tmm>

- book page (including tutorial lecture slides)

<http://www.cs.ubc.ca/~tmm/vadbook>

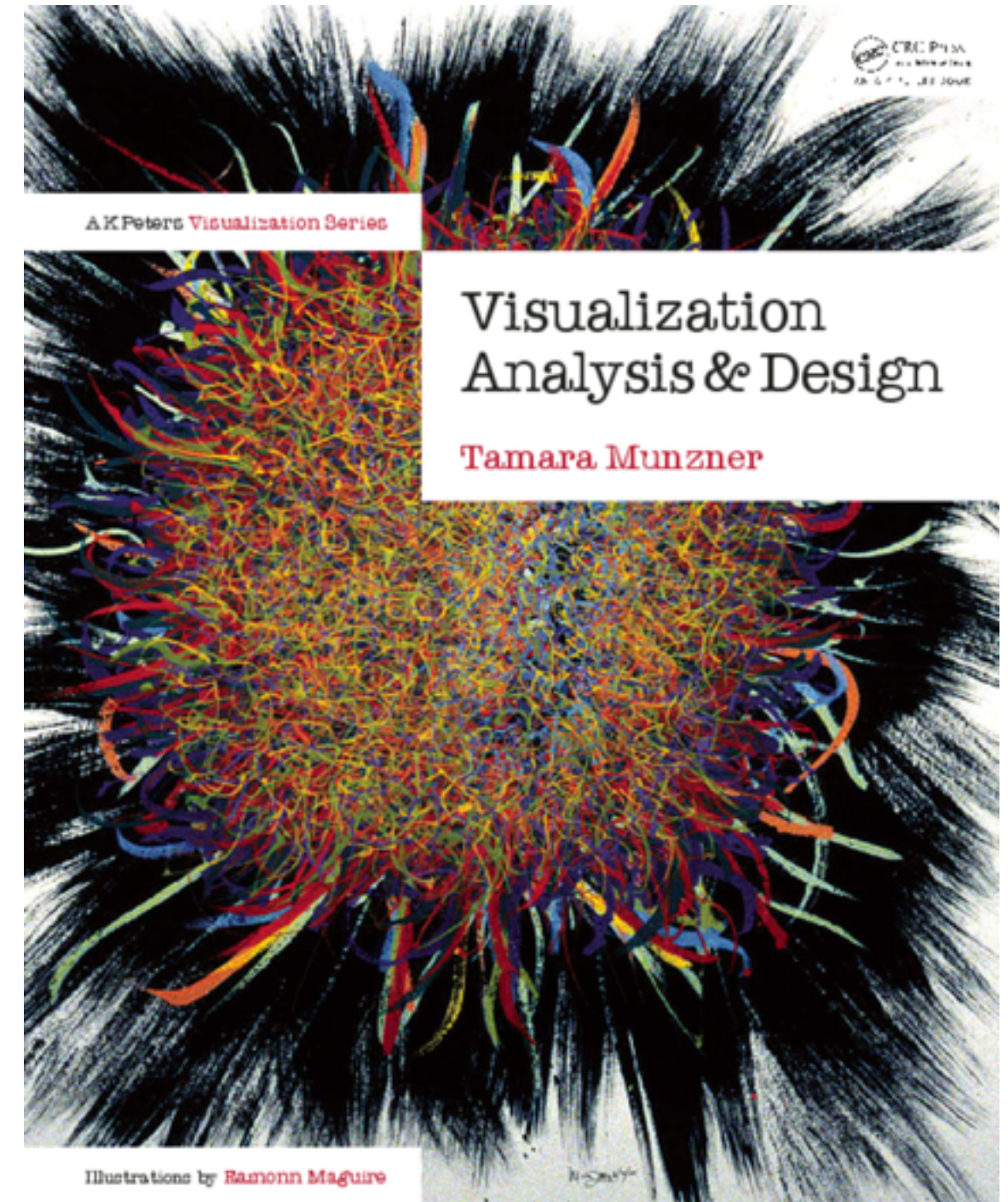
– 20% promo code for book+ebook combo:  
HVN17

– <http://www.crcpress.com/product/isbn/9781466508910>

– illustrations: Eamonn Maguire

- this talk

[www.cs.ubc.ca/~tmm/talks.html#visualise19](http://www.cs.ubc.ca/~tmm/talks.html#visualise19)



Visualization Analysis and Design.  
Munzner. A K Peters Visualization Series, CRC Press, Visualization Series, 2014.