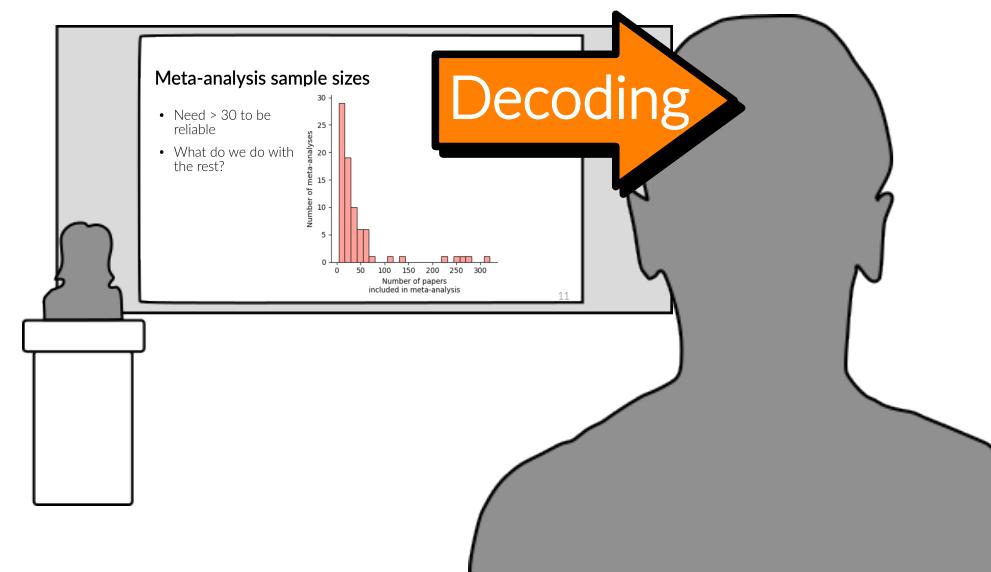


# Introduction to Data Visualization

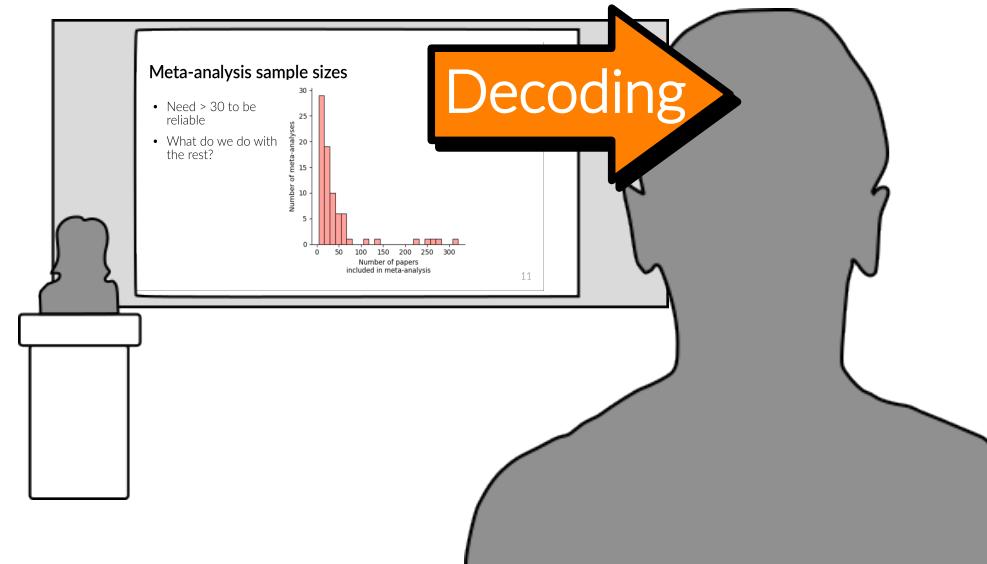
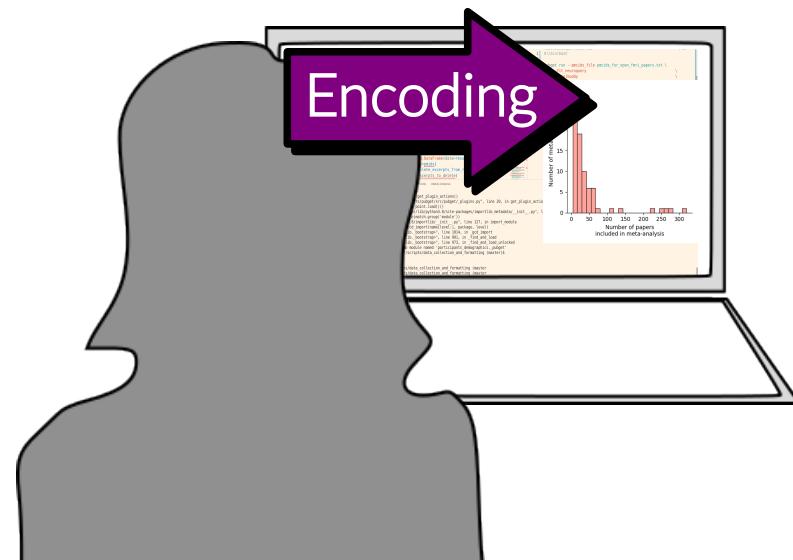
## Part 1: Decoding

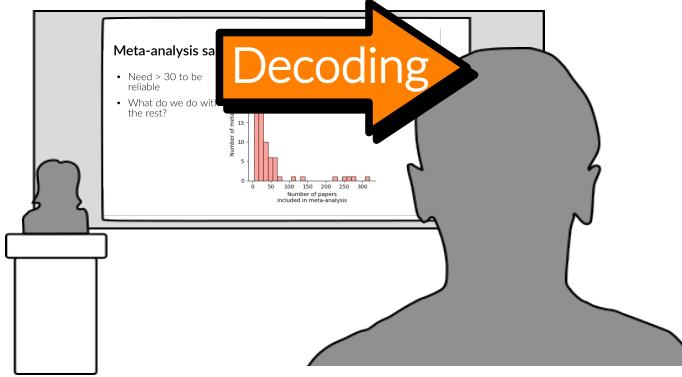
Kendra Oudyk



# Goal

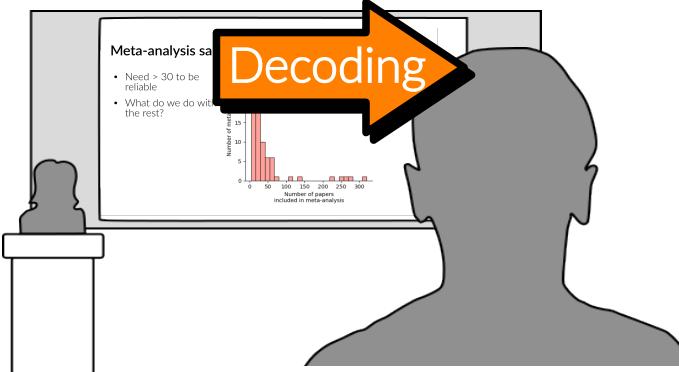
Use principles of visual **encoding** and **decoding**  
to **efficiently** create visualizations  
that are **effective** and **reproducible**





To plan an **effective visualization**, we need to think about

- **Message**
  - **What** we want to communicate
- **Perception**
  - **How best** to communicate it
- **Conventions**
  - **How** it's usually communicated
- **Context**
  - **Where** it will be seen

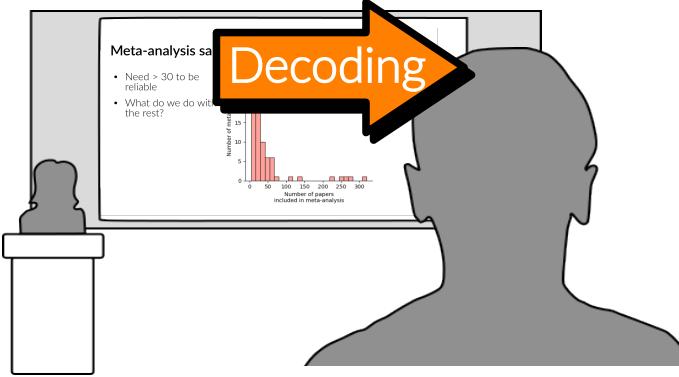


To plan an **effective visualization**, we need to think about

- **Message**
  - What we want to communicate
- **Perception**
  - How best to communicate it
- **Conventions**
  - How it's usually communicated
- **Context**
  - Where it will be seen

# Message

- Raw data has no message
- Abstract it
  - “There are more males than females in science”  
--> A difference between magnitudes
  - “These brain areas activate together”  
--> A grouping / pattern

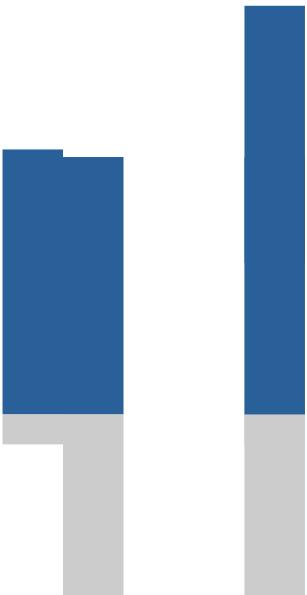


Decoding

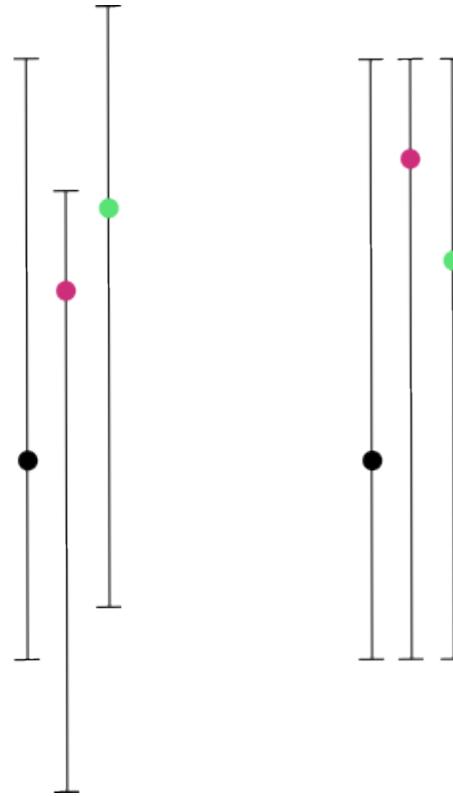
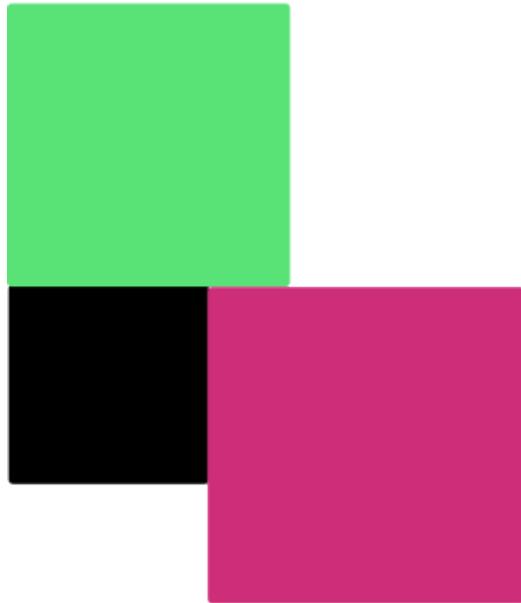
To plan an **effective visualization**, we need to think about

- **Message**
  - What we want to communicate
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  - How best to communicate it
- **Conventions**
  - How it's usually communicated
- **Context**
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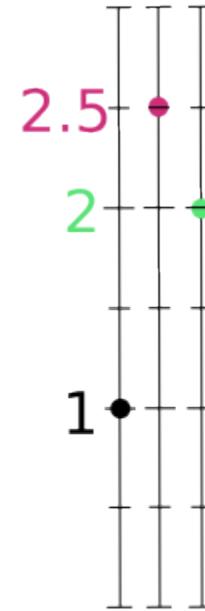
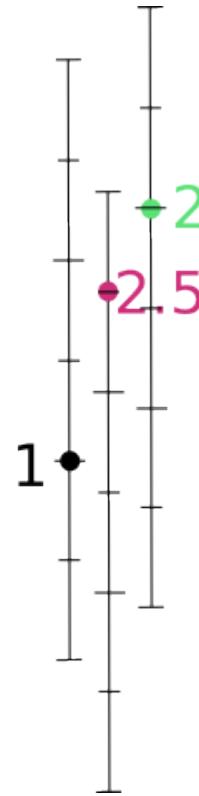
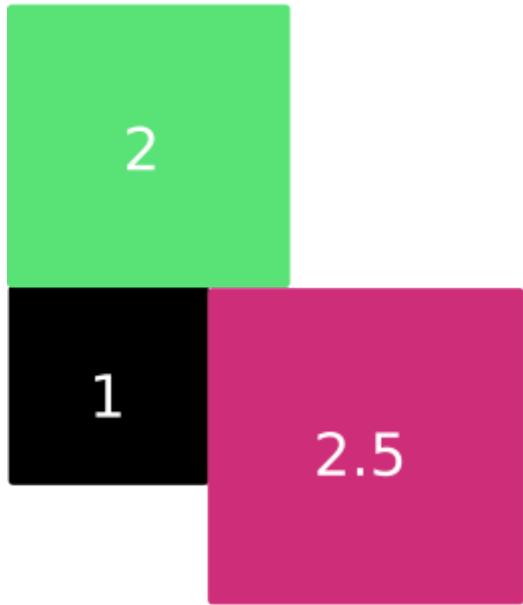
# Which blue bar is bigger?



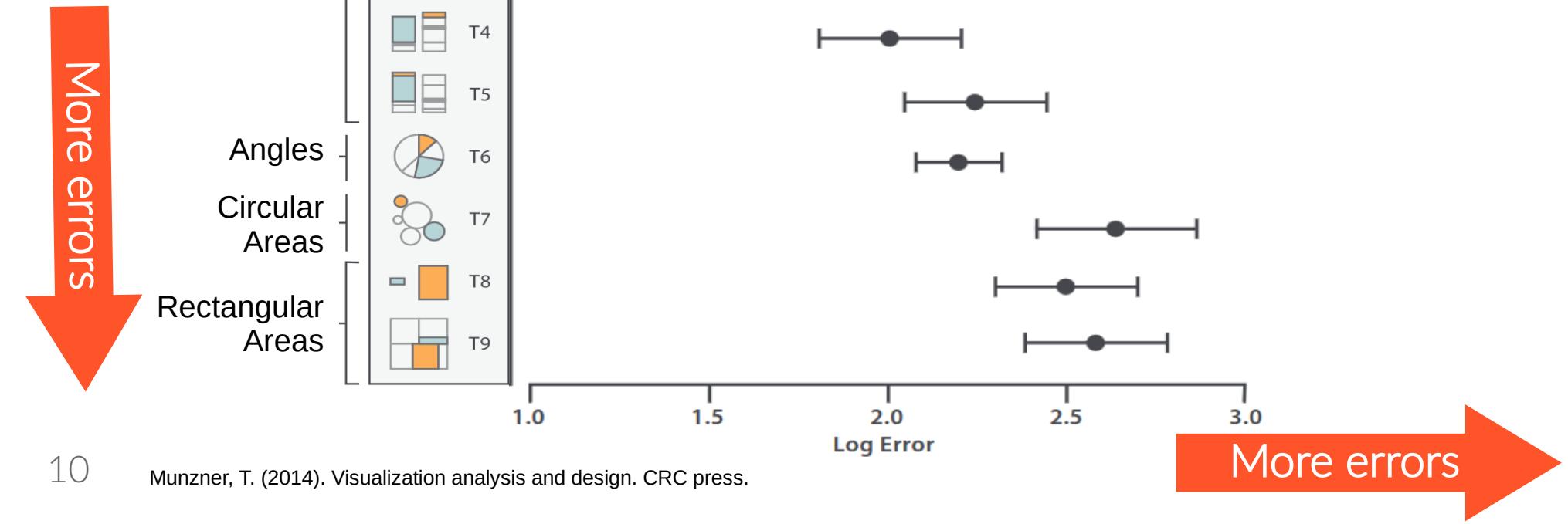
# Which is 2x black, green or pink?



# Which is 2x black, green or pink?



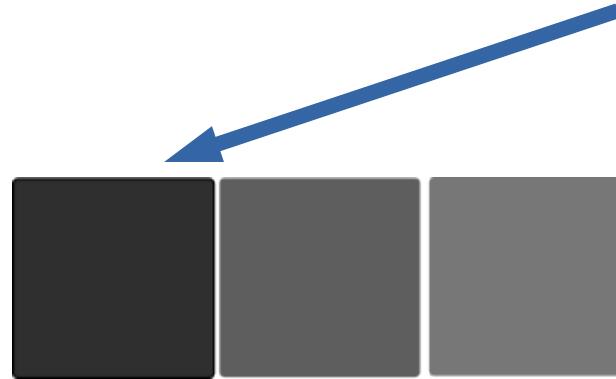
# We're better at judging aligned positions



# Decoding values vs. patterns

- “There are more males than females in science”  
--> A difference between **magnitudes**
- “These brain areas activate together”  
--> A grouping / **pattern**

# Which is 2x lighter than the leftmost box?

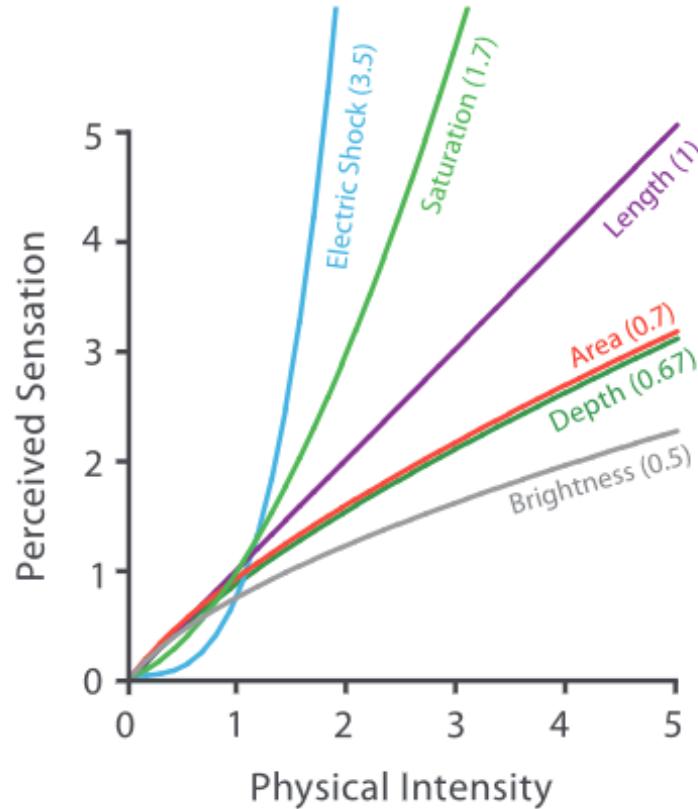


# Which is 2x lighter than the leftmost box?

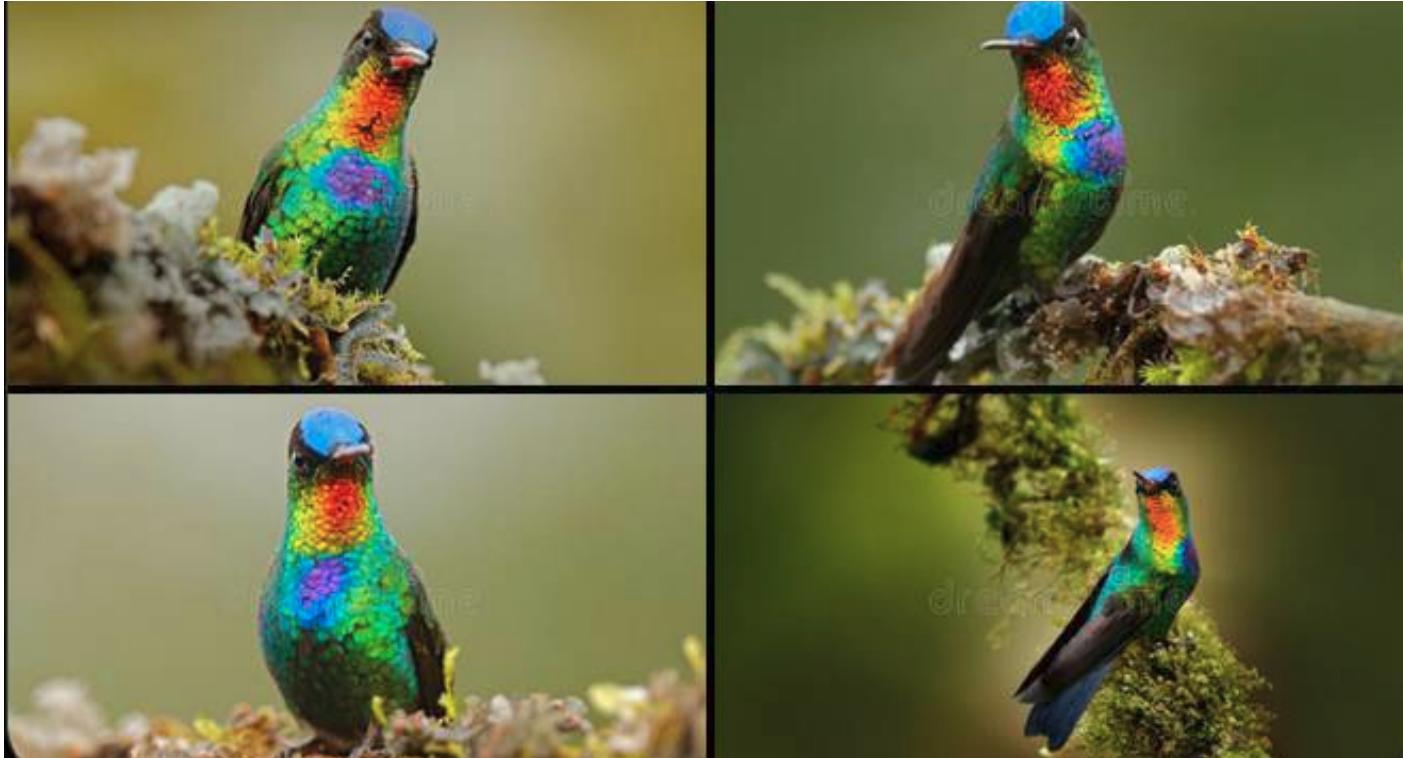


# Physical intensity vs perceived intensity

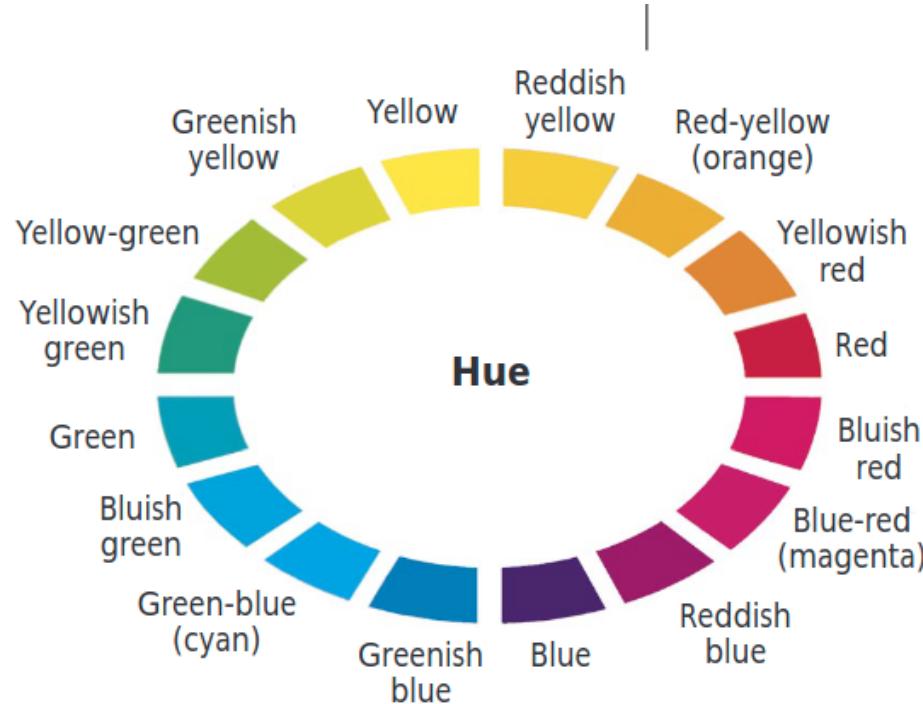
Steven's Psychophysical Power Law:  $S = I^N$



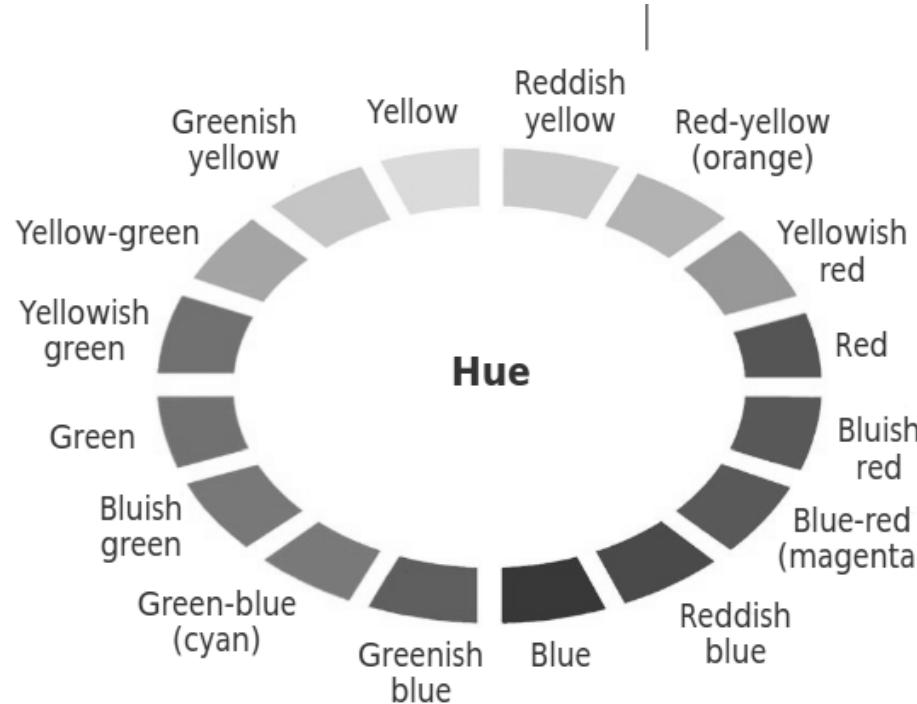
# Color: salient but complicated



# Hue: how we talk about color



# Luminance: an important subconscious cue



Which is  
lightest?



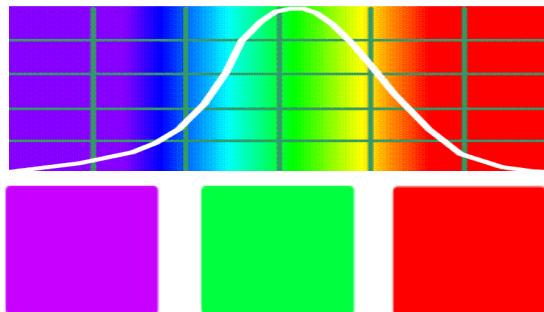


**Physical**  
Lightness



			
<b>Physical</b> Lightness	50	50	50
<b>Perceptual</b> Lightness	51	88	53

# Spectral sensitivity to luminance (lightness)



**Physical**  
Lightness

50	50	50
----	----	----

**Perceptual**  
Lightness

51	88	53
----	----	----

# Spectral sensitivity to luminance (lightness)

## HSL

(physically accurate)



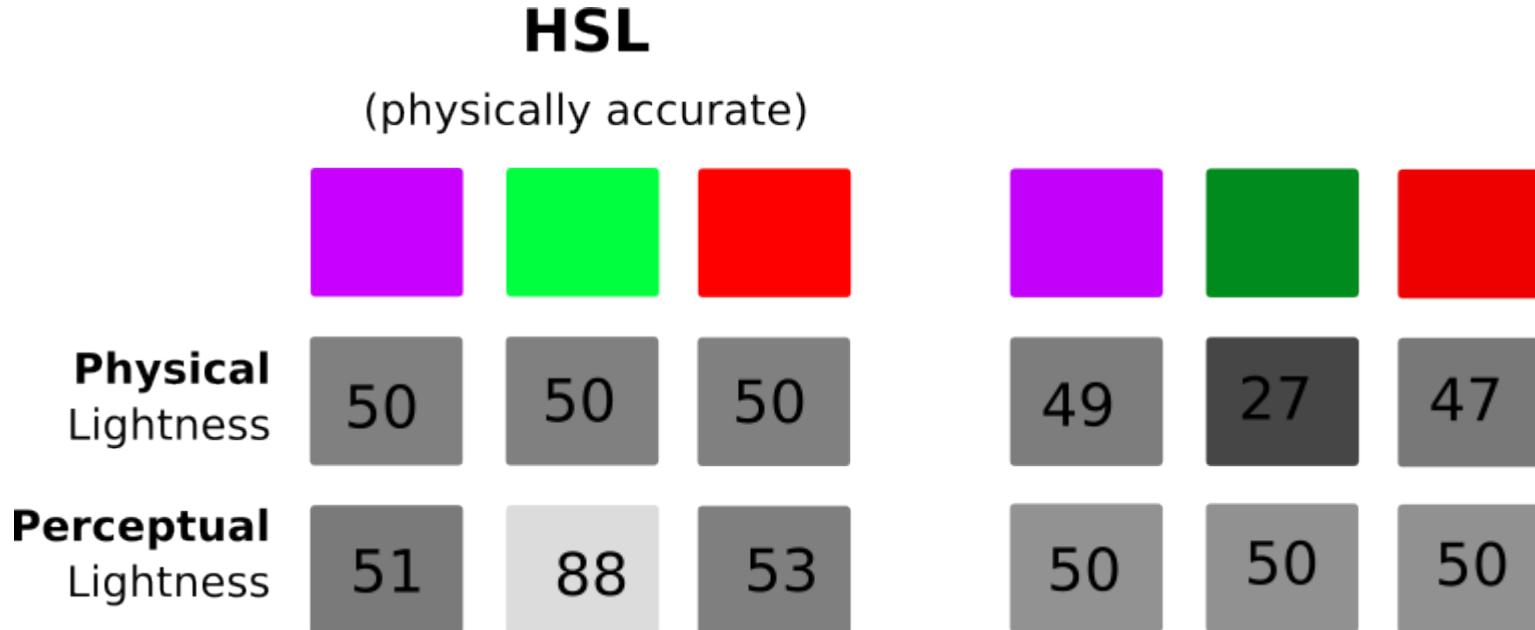
**Physical**  
Lightness

50	50	50
----	----	----

**Perceptual**  
Lightness

51	88	53
----	----	----

# Spectral sensitivity to luminance (lightness)

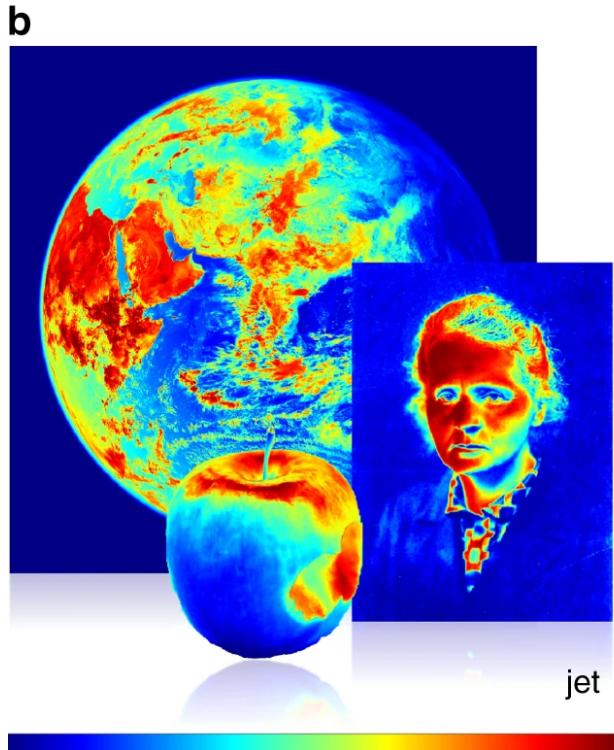


# Spectral sensitivity to luminance (lightness)

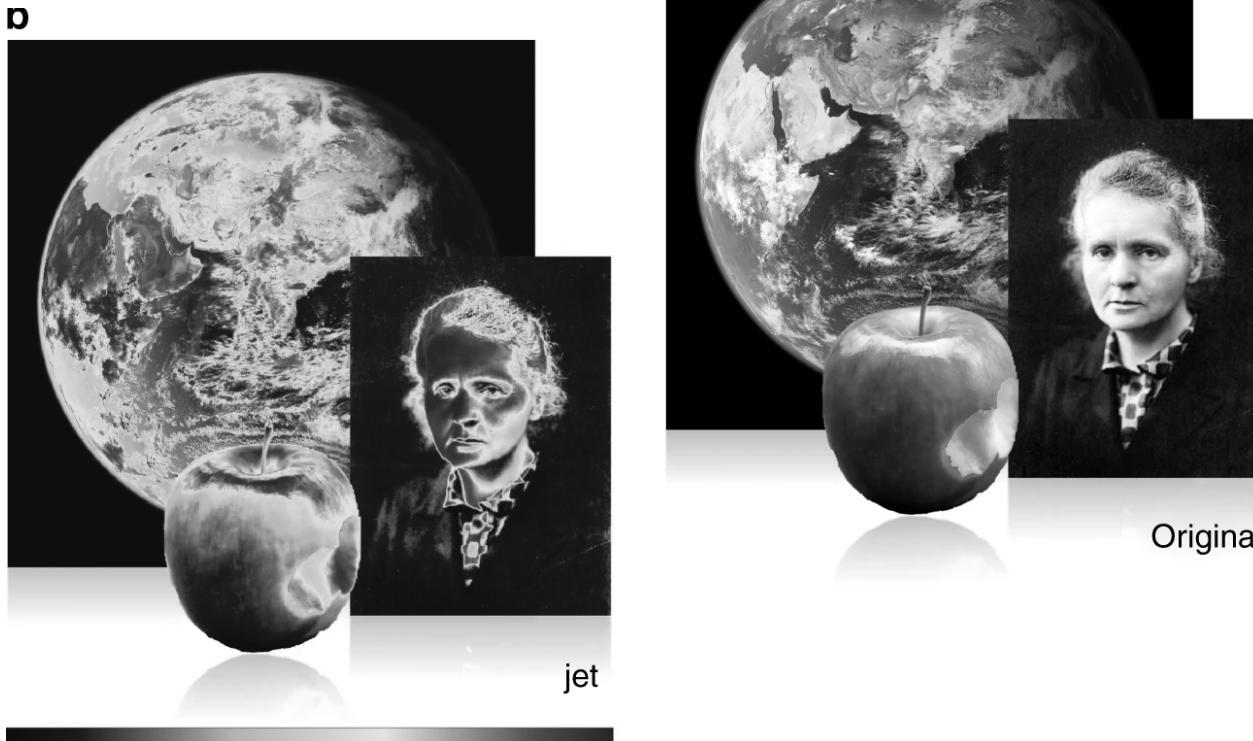
	<b>HSL</b> (physically accurate)			<b>H*S*L*</b> ( <b>psycho</b> physically accurate)		
						
<b>Physical</b> Lightness	50	50	50	49	27	47
<b>Perceptual</b> Lightness	51	88	53	50	50	50



# Named colors don't work well for ordered values

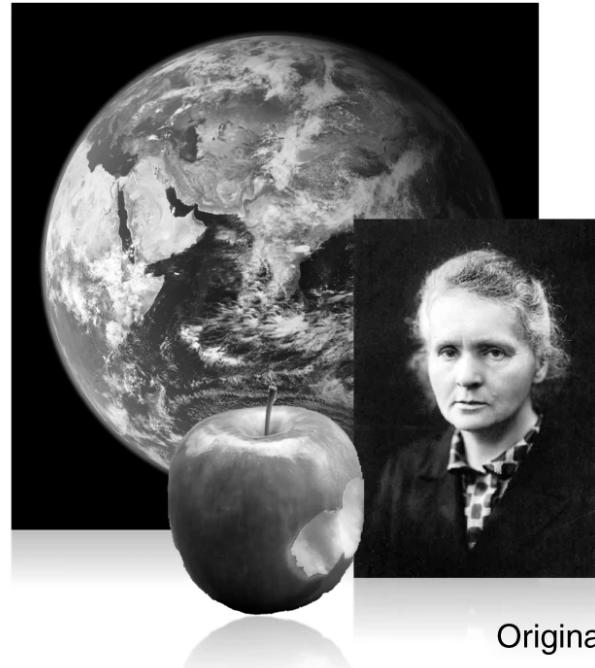
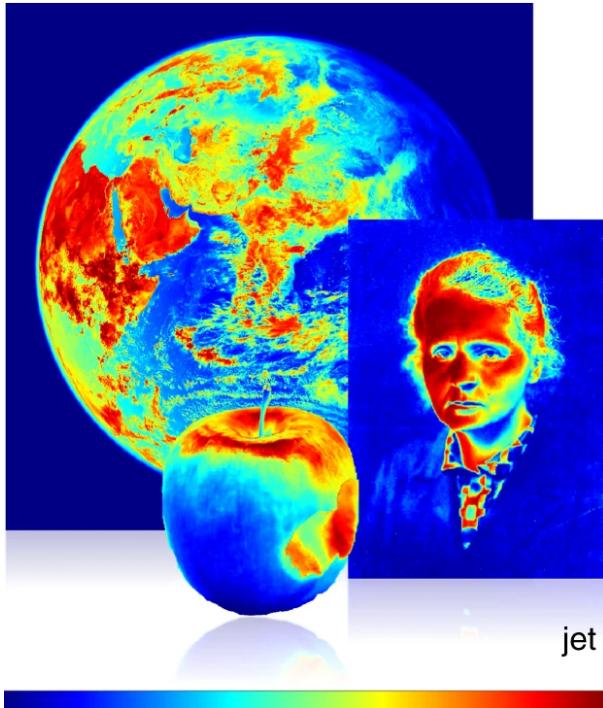


# Named colors don't work well for ordered values

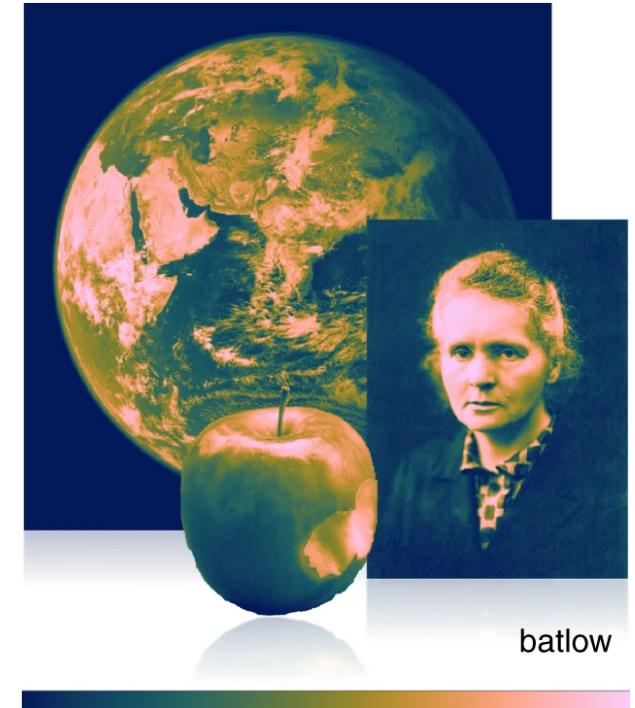


# Certain colormaps do work

b



c



# Certain colormaps do work

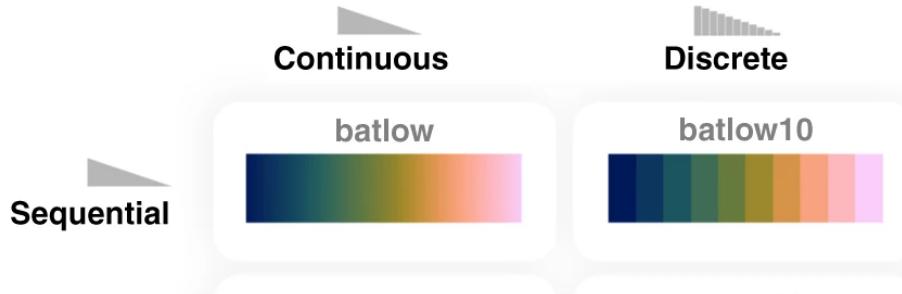
b



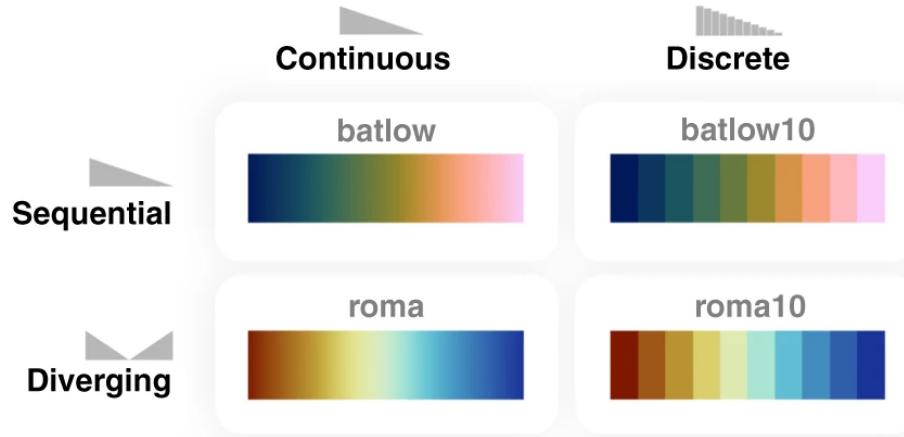
c



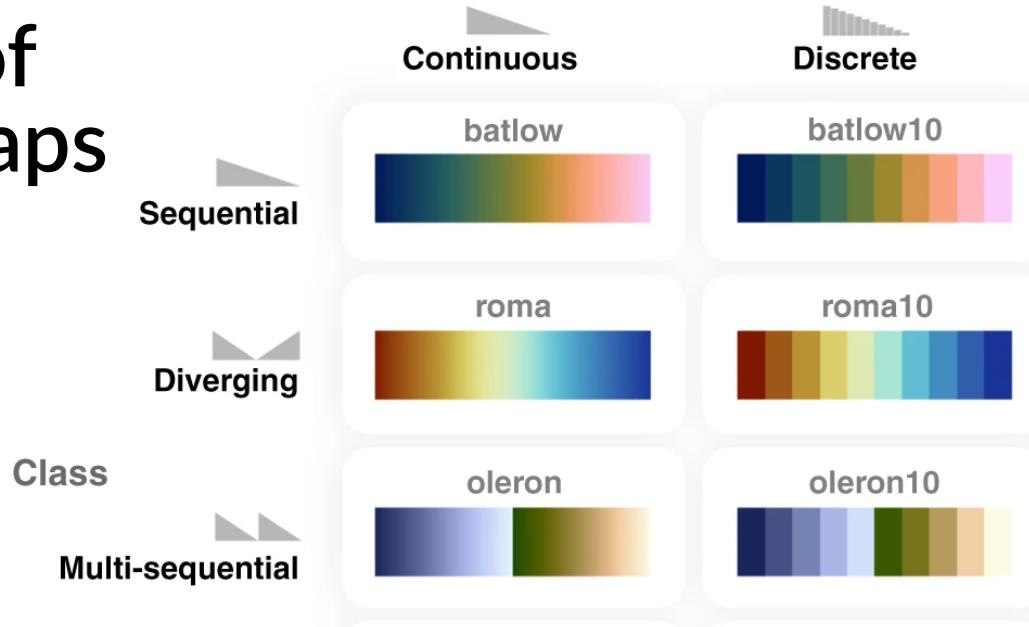
# Types of colormaps



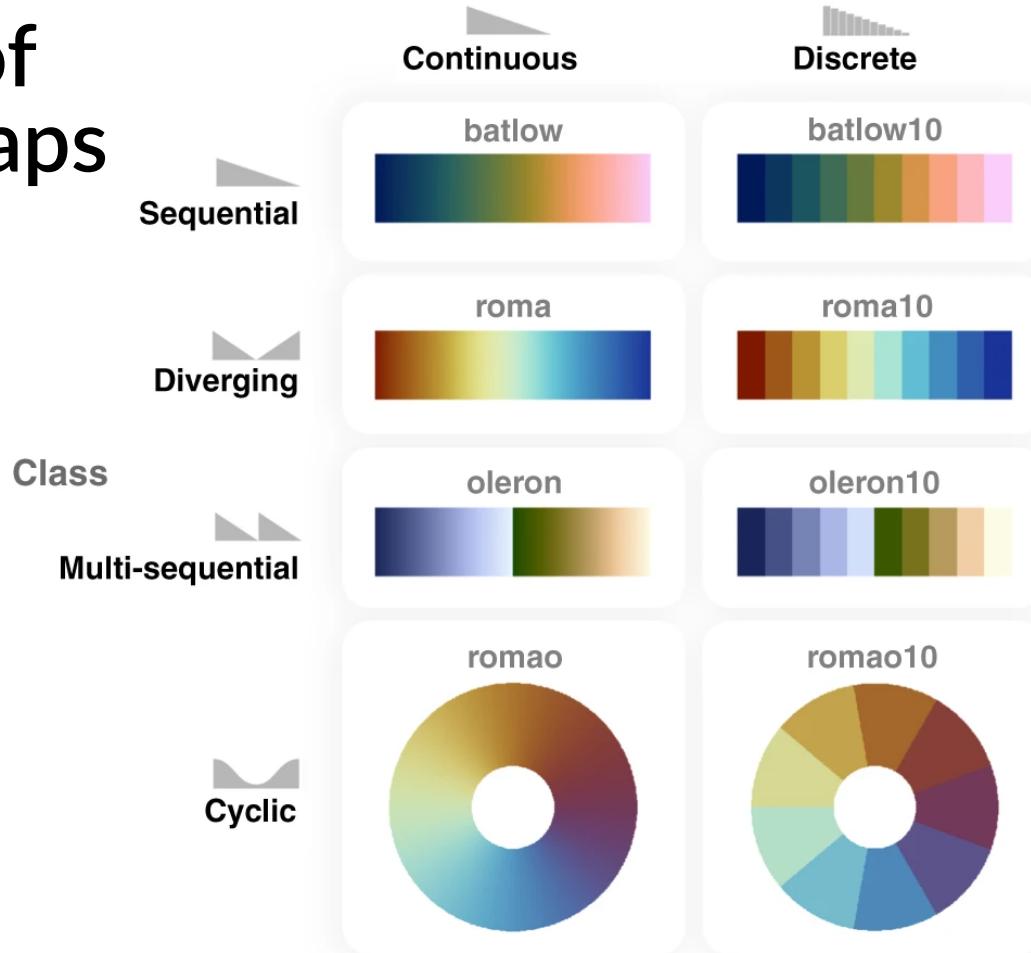
# Types of colormaps



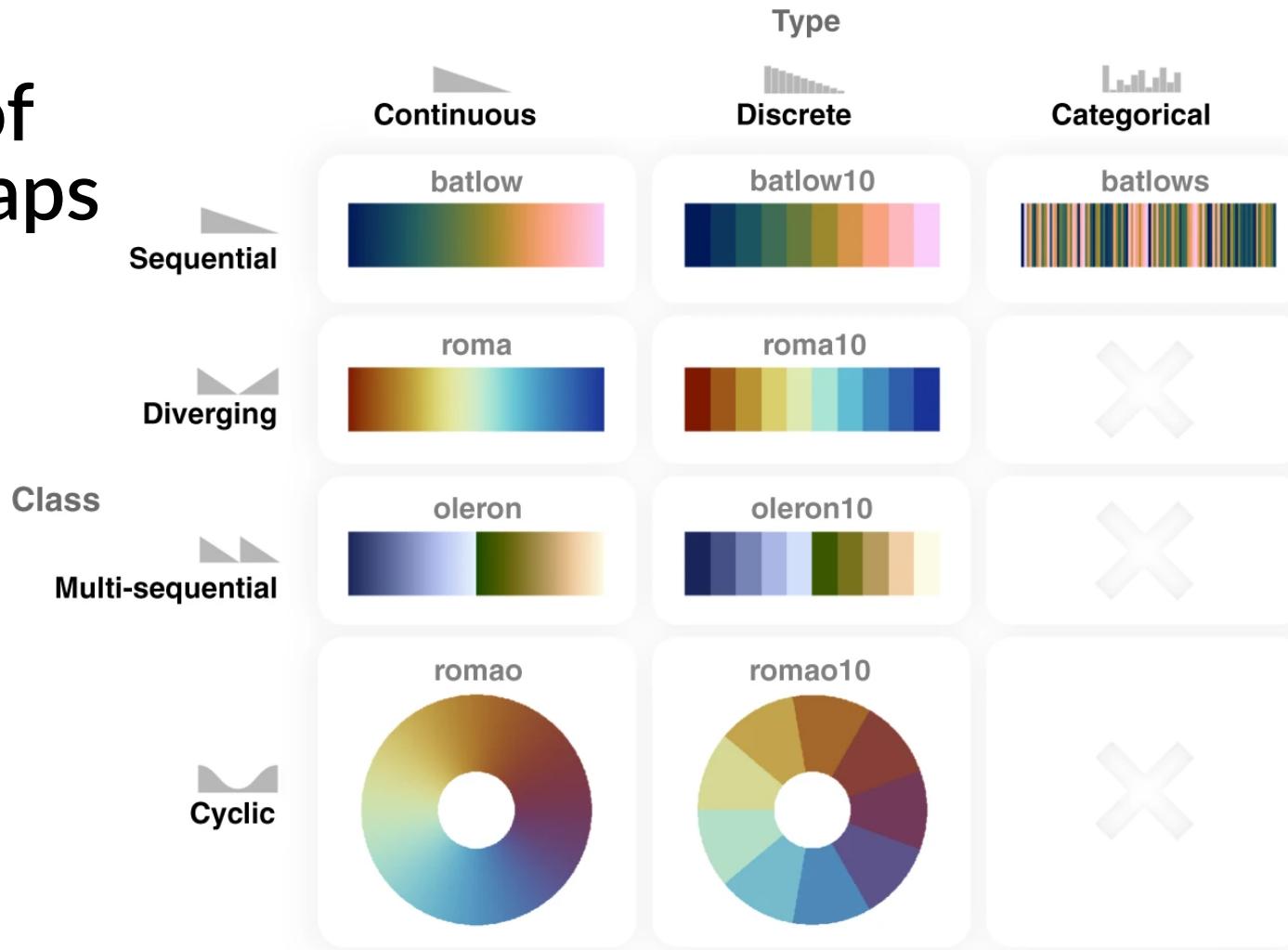
# Types of colormaps



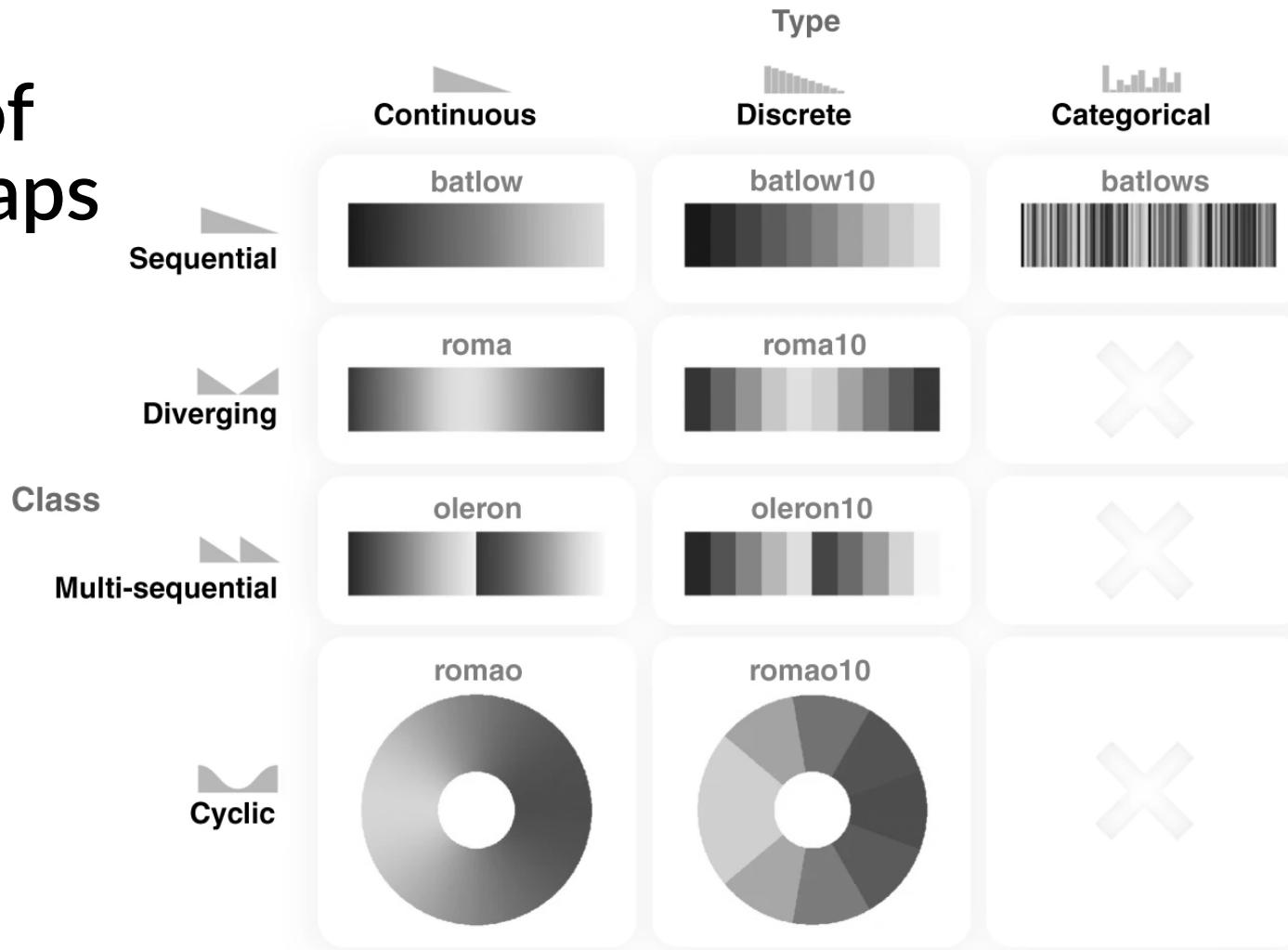
# Types of colormaps



# Types of colormaps



# Types of colormaps



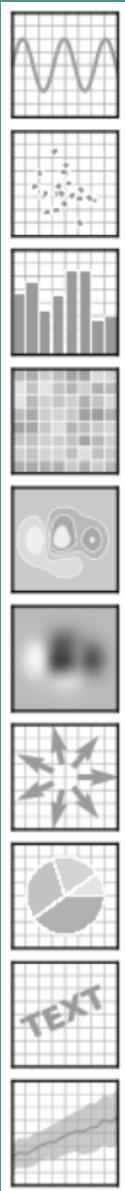
# How do I remember all that??

- Test yourself, your lab mate, your friend  
“Which bar is higher?”
- Look at the image in grayscale



(For future reference)

# Choosing effective charts



## Channels: Expressiveness Types and Effectiveness Ranks

### ⇒ **Magnitude Channels: Ordered Attributes**

Position on common scale



Position on unaligned scale



Length (1D size)



Tilt/angle



Area (2D size)



Depth (3D position)



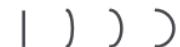
Color luminance



Color saturation



Curvature



Volume (3D size)



### ⇒ **Identity Channels: Categorical Attributes**

Spatial region



Color hue



Motion



Shape



Text

Fr  
Ca

Canada France Canada France

[https://matplotlib.org/cheatsheets/\\_images/cheatsheets-1.png](https://matplotlib.org/cheatsheets/_images/cheatsheets-1.png)

Munzner, T. (2014). Visualization analysis and design. CRC press.

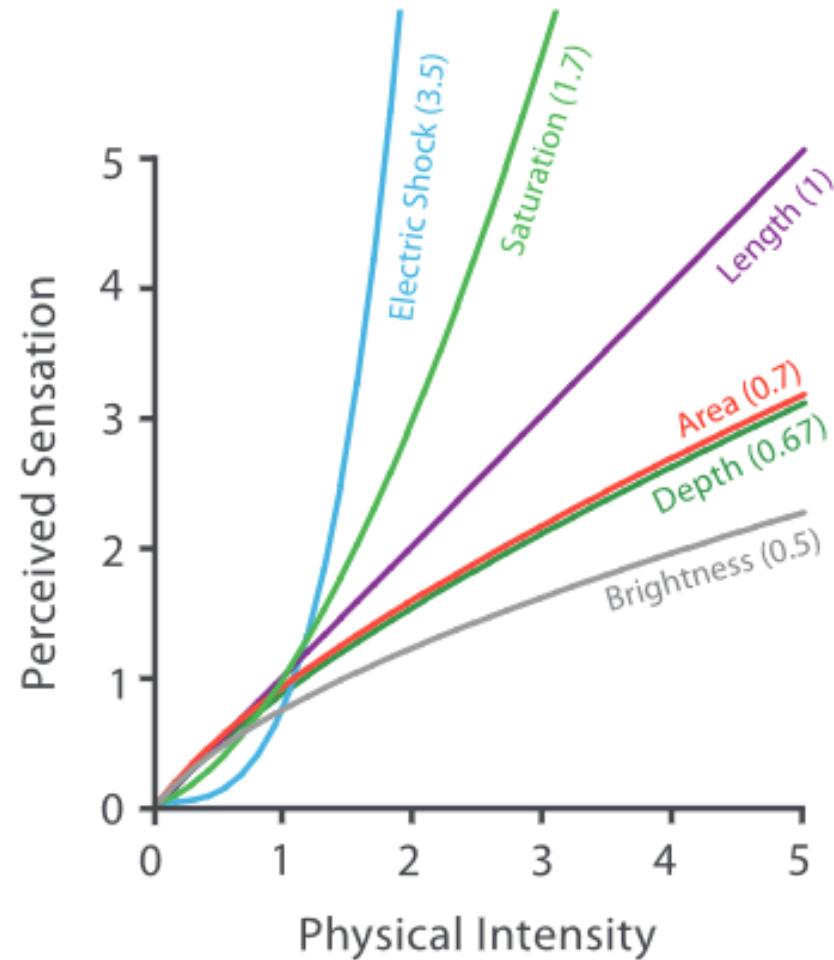


# Lineplot

Ordered

Categorical

Steven's Psychophysical Power Law:  $S = I^N$



# Lineplot

Ordered

Position on a common scale

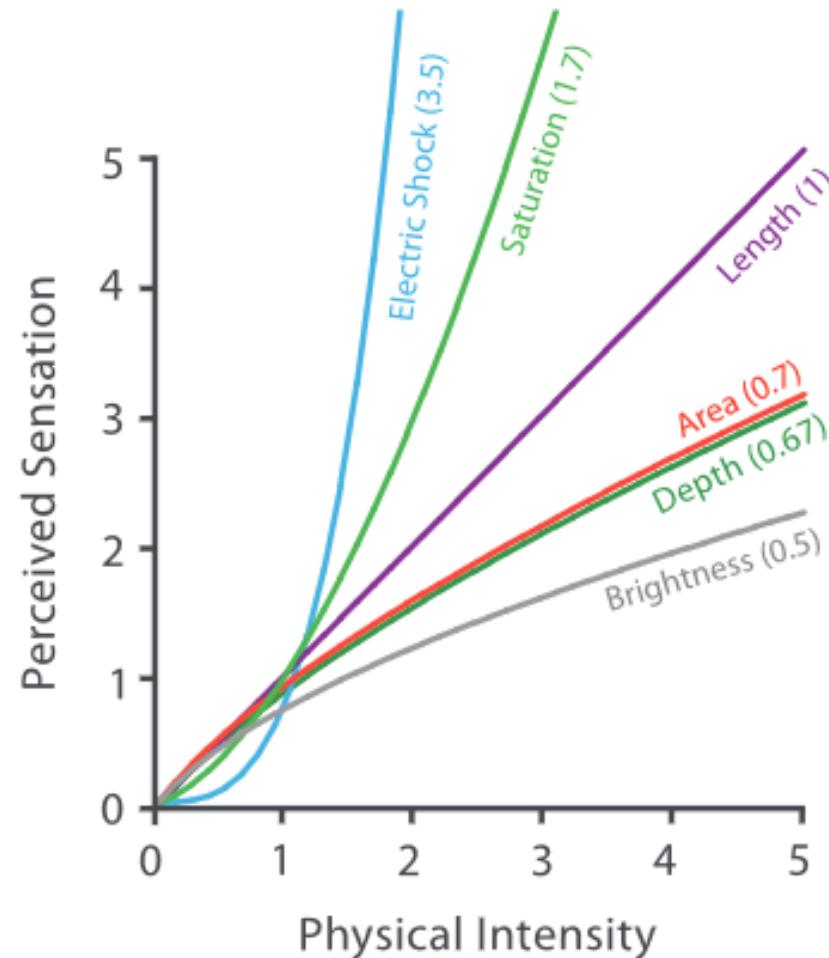


Text (equation)

Canada Canada Canada  
France France France

Categorical

Steven's Psychophysical Power Law:  $S = I^N$



# Lineplot

## Ordered

Position on a common scale



Canada Canada Canada  
France France France

Text (equation)

## Categorical

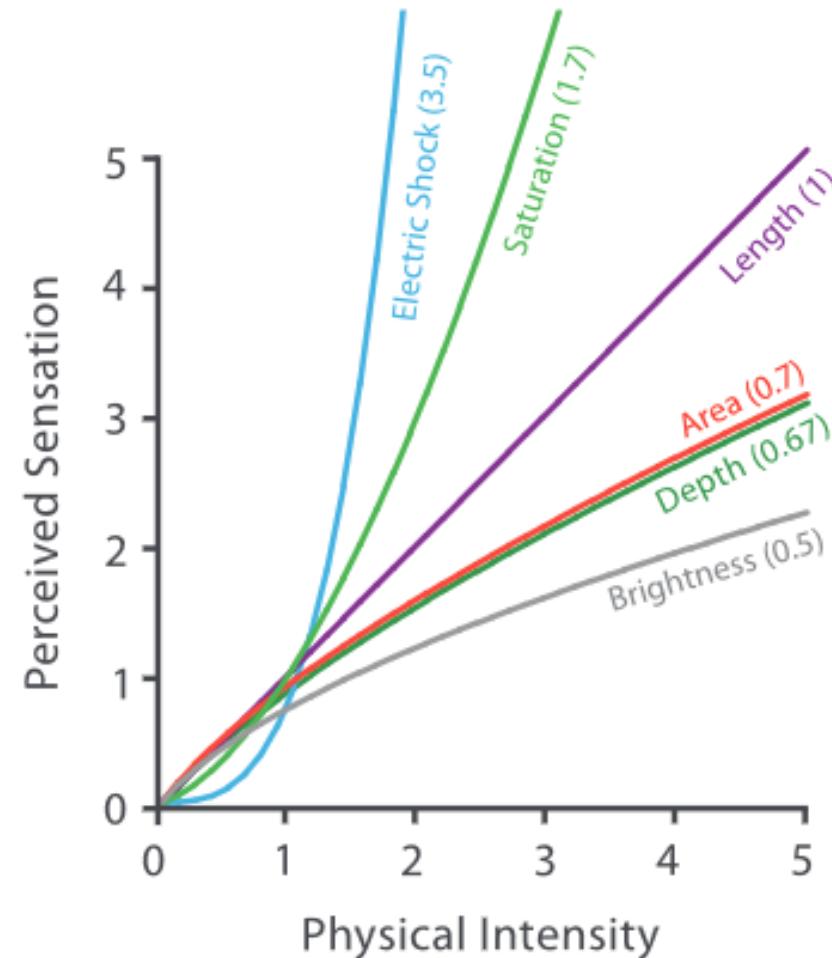
Hue



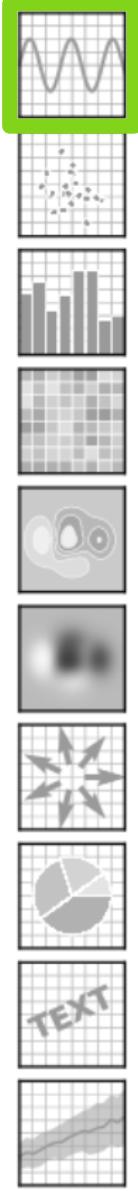
Text (identity)

Canada Canada Canada  
France France France

Steven's Psychophysical Power Law:  $S = I^N$



# Lineplot



## Channels: Expressiveness Types and Effectiveness Ranks

### ⇒ **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)



### ⇒ **Identity** Channels: **Categorical Attributes**

Spatial region



Color hue



Motion



Shape



Text



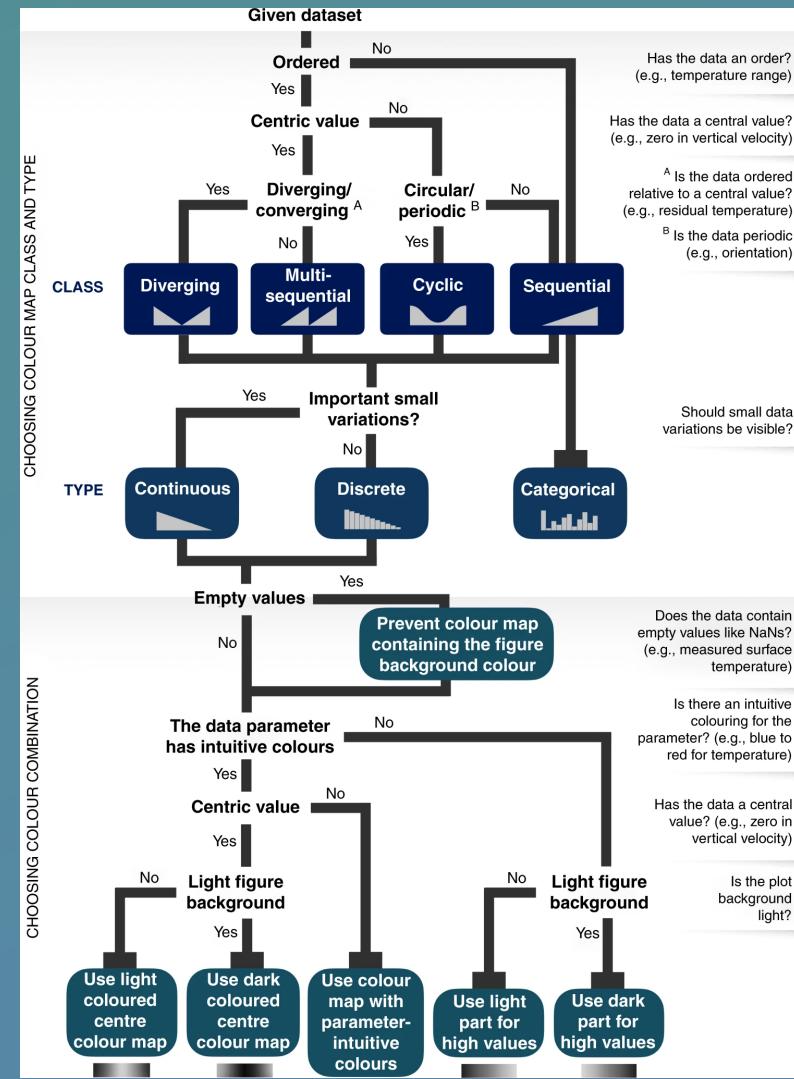
Most

Effective

Least

(For future reference)

# Choosing effective colormaps



Activities Firefox Web Browser • Apr 26 7:51 PM • 100 %

Frontiers | rogowitz a IEEE Xplor Data visual IEEE Xplor Fig. 2: Colo Choosing + - X

https://matplotlib.org/stable/tutorials/colors/colormaps.html#sphx-glr-tutorials-colors-colormaps

# matplotlib

Plot types Examples Tutorials Reference User guide Develop Releases stable

## Section Navigation

- Introductory
- Intermediate
- Advanced
- Colors
  - Specifying colors
  - Customized Colorbars Tutorial
  - Creating Colormaps in Matplotlib
  - Colormap Normalization
- Choosing Colormaps in Matplotlib
  - Text
  - Toolkits
  - Provisional

## Sequential

For the Sequential plots, the lightness value increases monotonically through the colormaps. This is good. Some of the  $L^*$  values in the colormaps span from 0 to 100 (binary and the other grayscale), and others start around  $L^* = 20$ . Those that have a smaller range of  $L^*$  will accordingly have a smaller perceptual range. Note also that the  $L^*$  function varies amongst the colormaps: some are approximately linear in  $L^*$  and others are more curved.

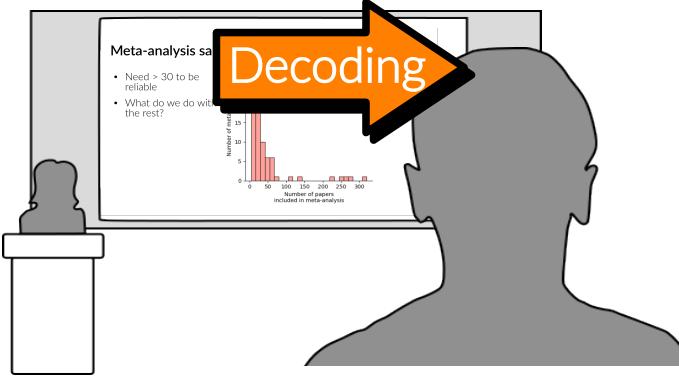
```
plot_color_gradients('Perceptually Uniform Sequential',
                     ['viridis', 'plasma', 'inferno', 'magma', 'cividis'])
```

Perceptually Uniform Sequential colormaps

```
plot_color_gradients('Sequential',
                     ['Greys', 'Purples', 'Blues', 'Greens', 'Oranges', 'Reds',
                      'YlOrRd', 'OrRd', 'PuRd', 'RdPu', 'BuPu', 'GnBu',
                      'PuBu', 'RdGy', 'BuGn', 'GnBu_r', 'PuBu_r', 'RdGy_r',
                      'BuGn_r'])
```

On this page

- Overview
- Classes of colormaps
  - Sequential
  - Sequential2
  - Diverging
  - Cyclic
  - Qualitative
  - Miscellaneous
- Lightness of Matplotlib colormaps
- Grayscale conversion
- Color vision deficiencies
- References

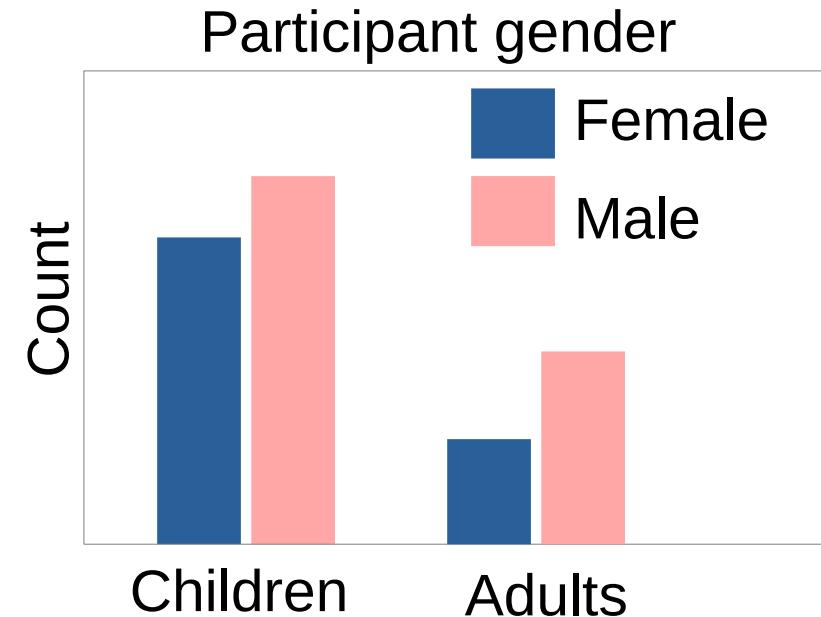


Decoding

To plan an **effective visualization**, we need to think about

- **Message**
  - What we want to communicate
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  - How it's usually communicated
- **Context**
  - Where it will be seen

# Culture: Color associations



# Science: Rainbow colormaps are disliked

← **Tweet**

 **Patrick Mineault**   
@patrickmineault

Does anybody else have a visceral negative reaction when they see the jet colormap?

# Science: Rainbow colormaps are disliked

Chris Holdgraf 🐘 @choldgraf@hachyderm.io  
@choldgraf

Academia twitter: when you review papers, do you instruct authors to change their colormap from jet to either viridis/parula?

Option	Percentage
yes	24.5%
no	36.2%
just wanna see answers	35.1%
I require plots in ASCII	4.3%

94 votes · Final results

1:48 PM · Apr 7, 2018

# Science: Rainbow colormaps are disliked?

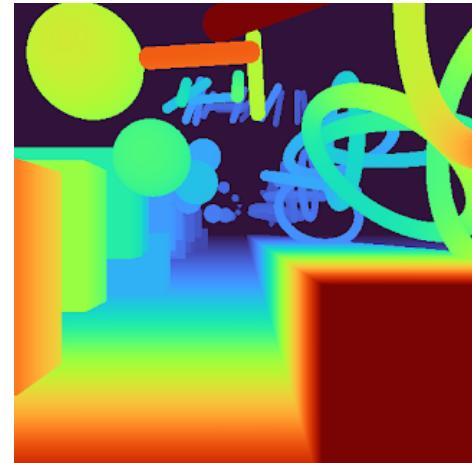


Simon Eickhoff  
@INM7\_ISN

Turbo, a colormap that looks like jet without its downsides

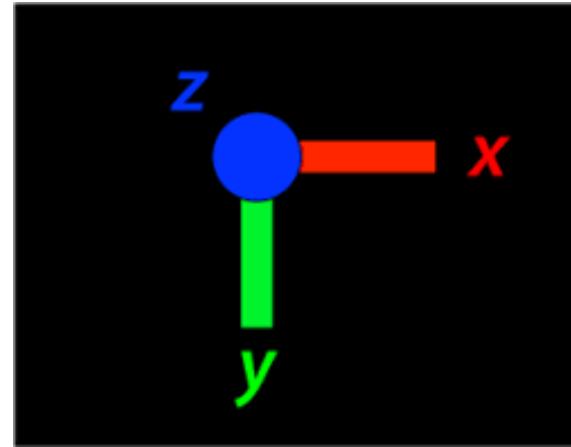
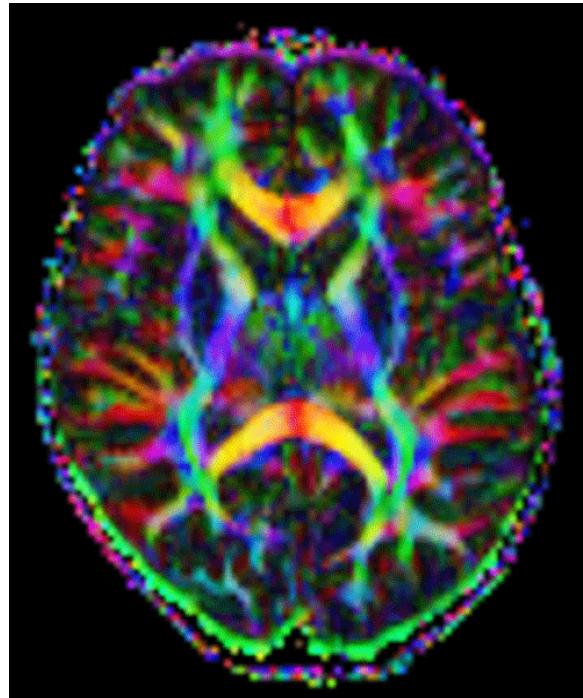
Great news for somebody like me, who likes jet as nameable colors are indispensable in many applications: Try explaining anybody, which shade of parula actually denotes the interesting finding

[buff.ly/30h9N8O](https://buff.ly/30h9N8O)



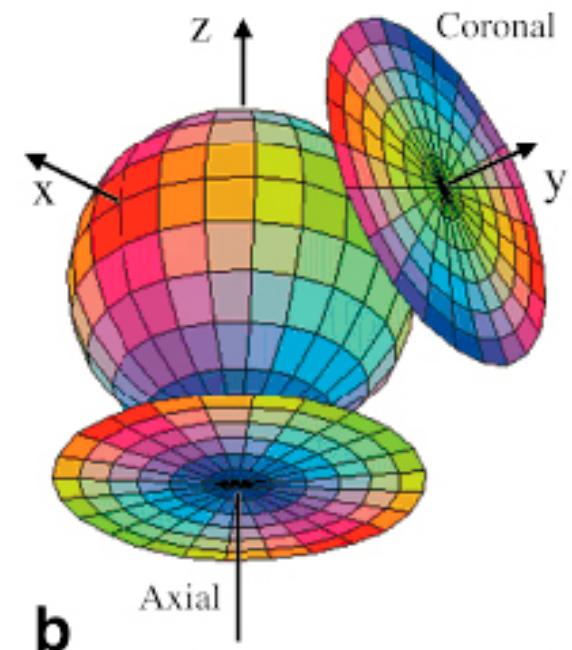
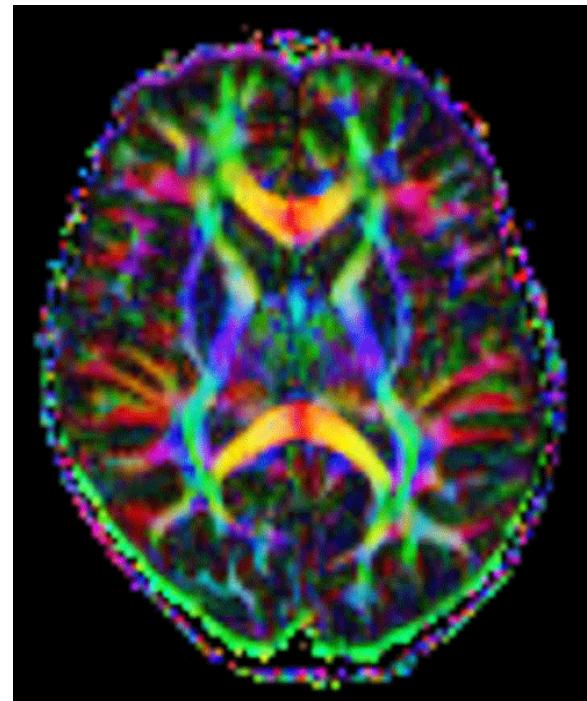
# Neuroscience: Colors = 3D direction

Principal Diffusion Direction



# Neuroscience: Colors = 3D direction

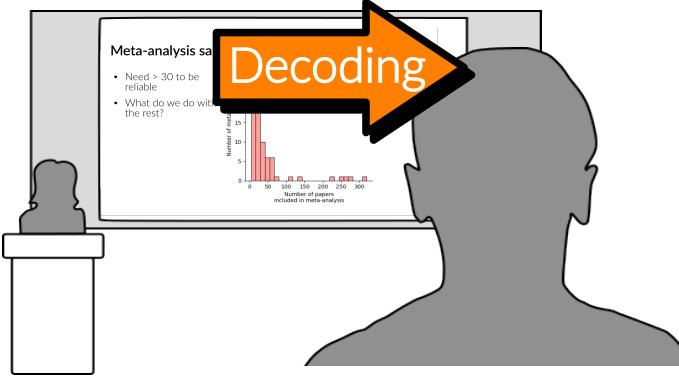
Principal Diffusion Direction



(For future reference)

# Examples of visualization conventions

- Culture
  - Pink is female
  - Time goes left to right
- Science
  - Rainbow colormaps are disliked
- Neuroscience
  - MRI in grayscale
  - DWI colors = directions

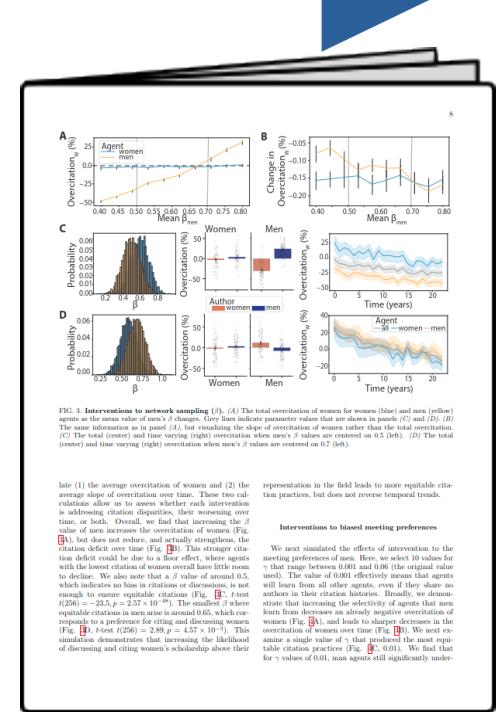
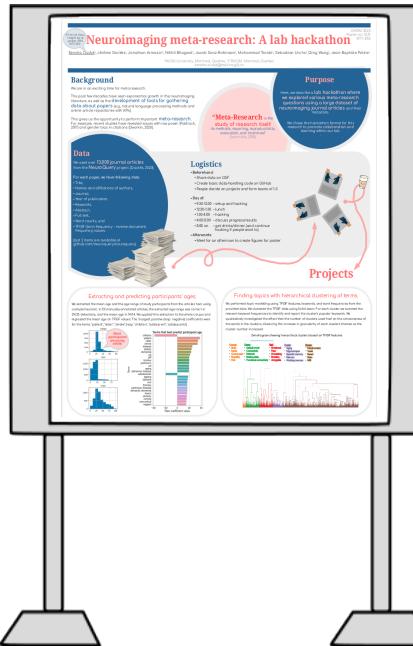
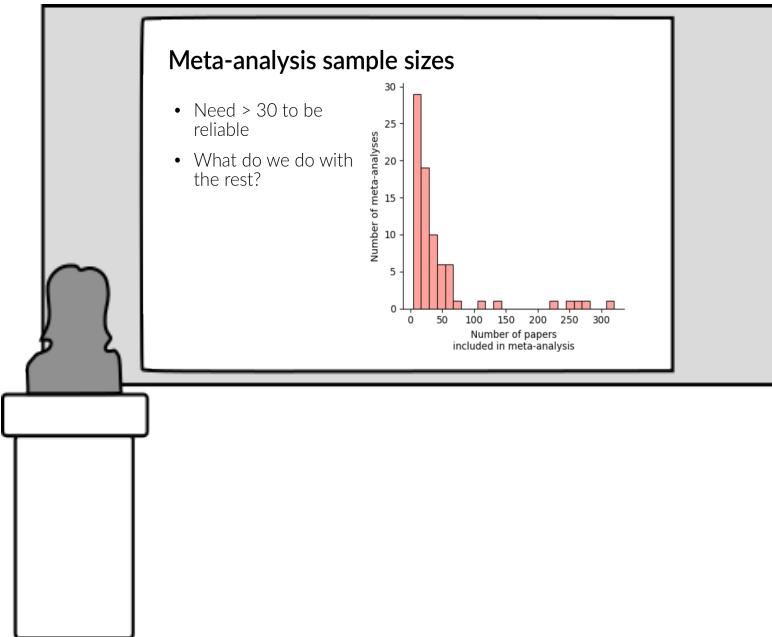


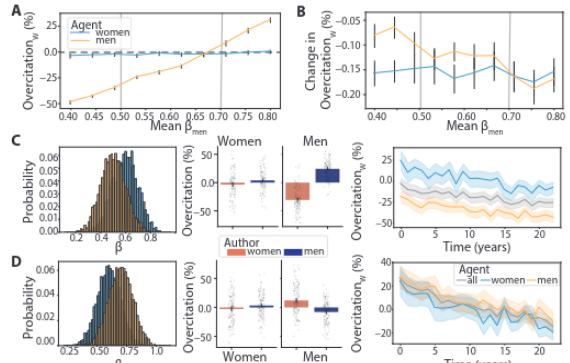
Decoding

To plan an **effective visualization**, we need to think about

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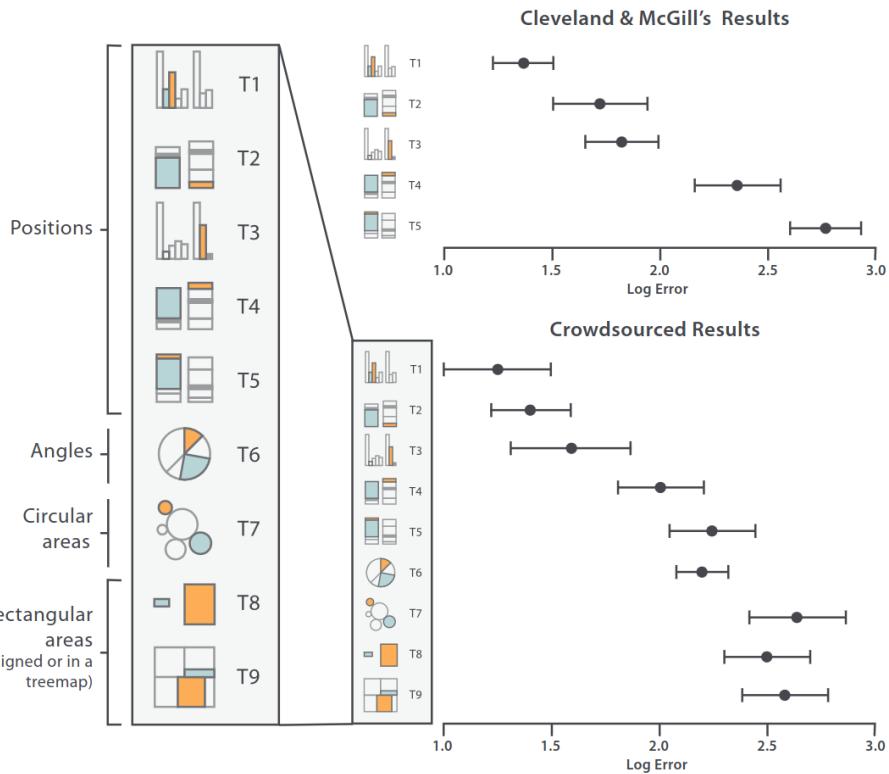
# More self-explanatory





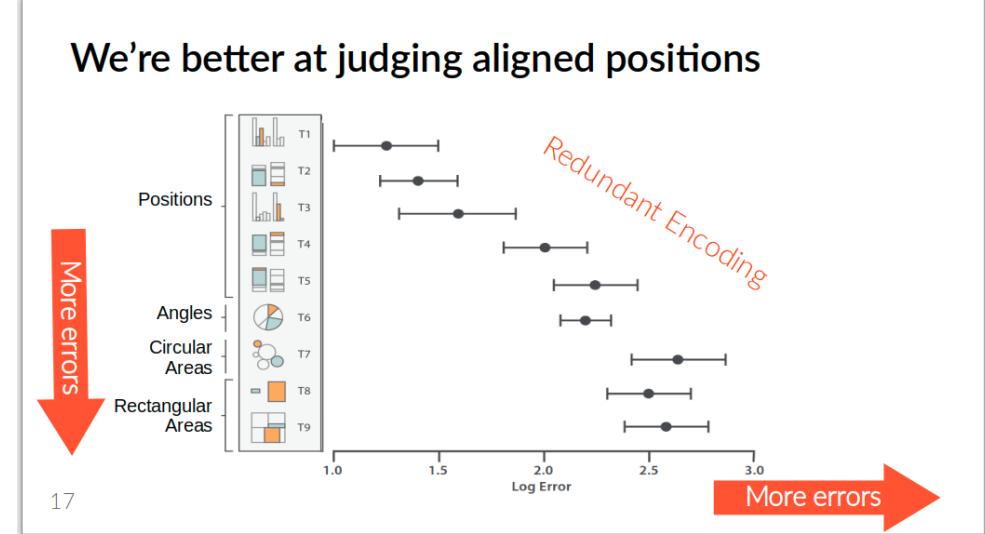
- How long would it take them to understand this slide?
- How long will they see the slide?

# E.g., Figure in textbook



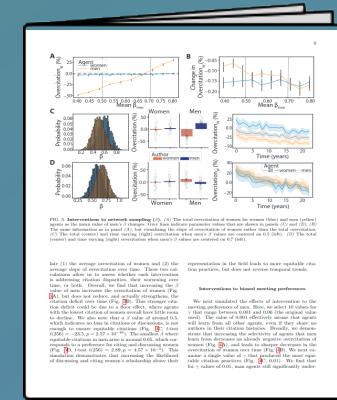
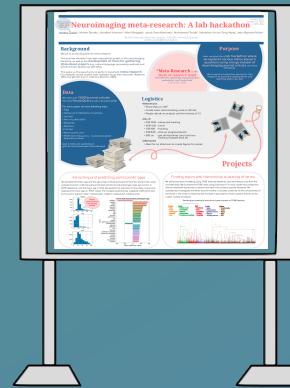
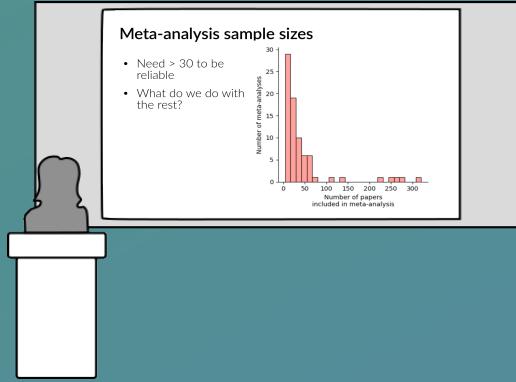
# My slide

We're better at judging aligned positions



(For future reference)

# Contextual adjustments



Time to understand

Proximity to viz

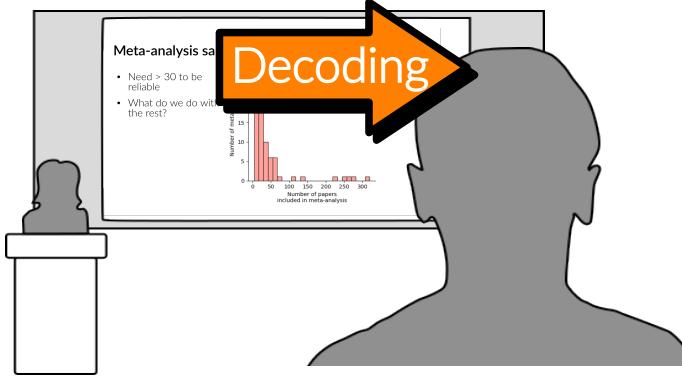
Less

Text explanations

More

Self-explanatory

Visual complexity



To plan an **effective visualization**, we need to think about

- **Message**
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# Example 1 – Simple data and figure

- Original paper on the ABIDE dataset
  - 964 subjects
    - 396 male
    - 51 female

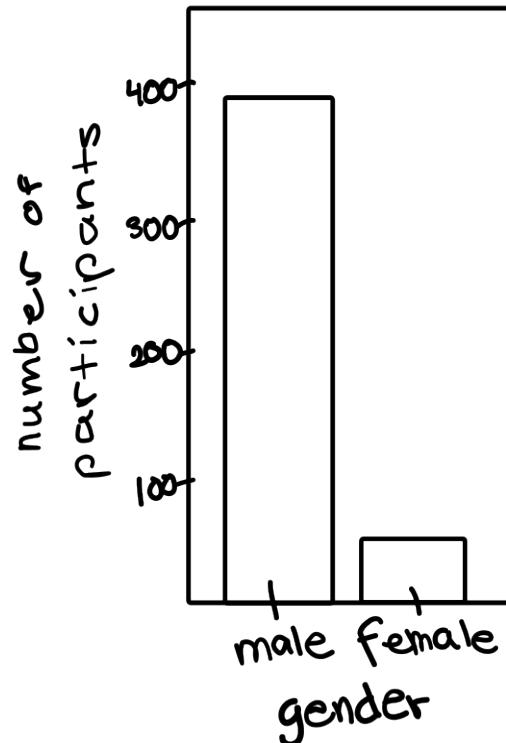
← Lets visualize this

# What's our message?

- More male than female participants
  - 2 categories, 2 values

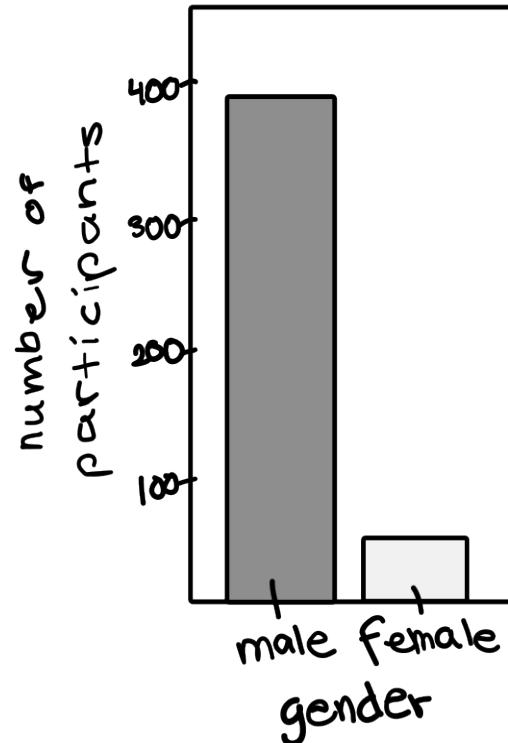
# How should we communicate this message?

- Clearly show 2 categories and 2 different values



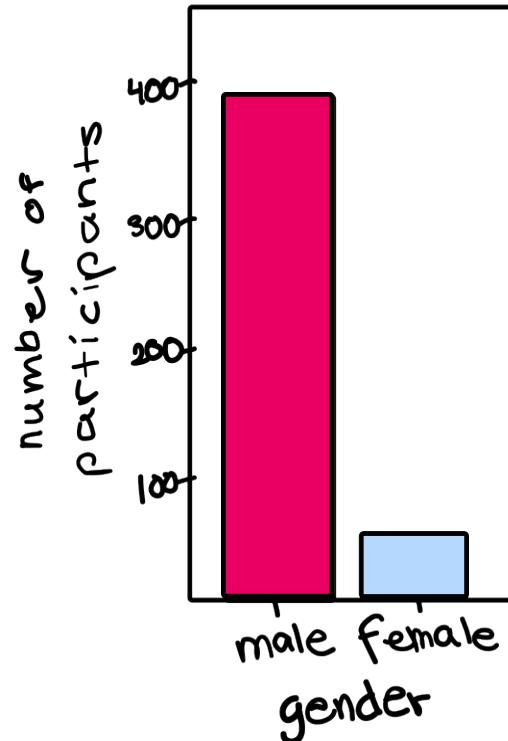
# How should we communicate this message?

- Clearly show 2 categories and 2 different values



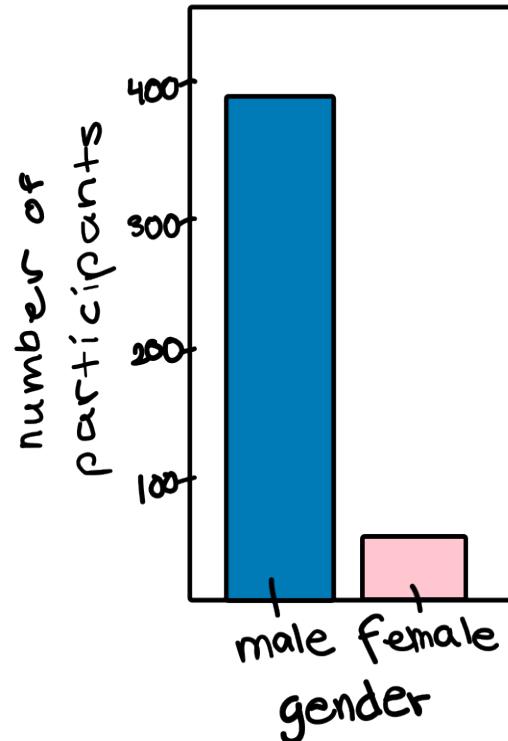
# How should we communicate this message?

- Clearly show 2 categories and 2 different values



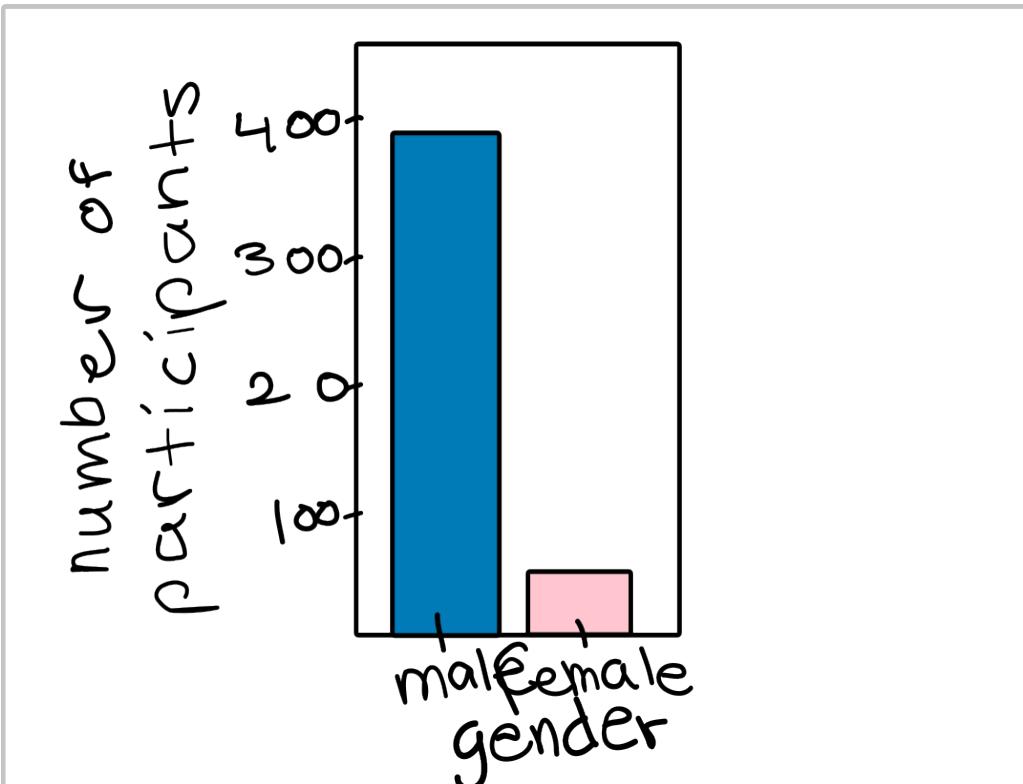
# Are there any conventions we should think about?

- Gender & color



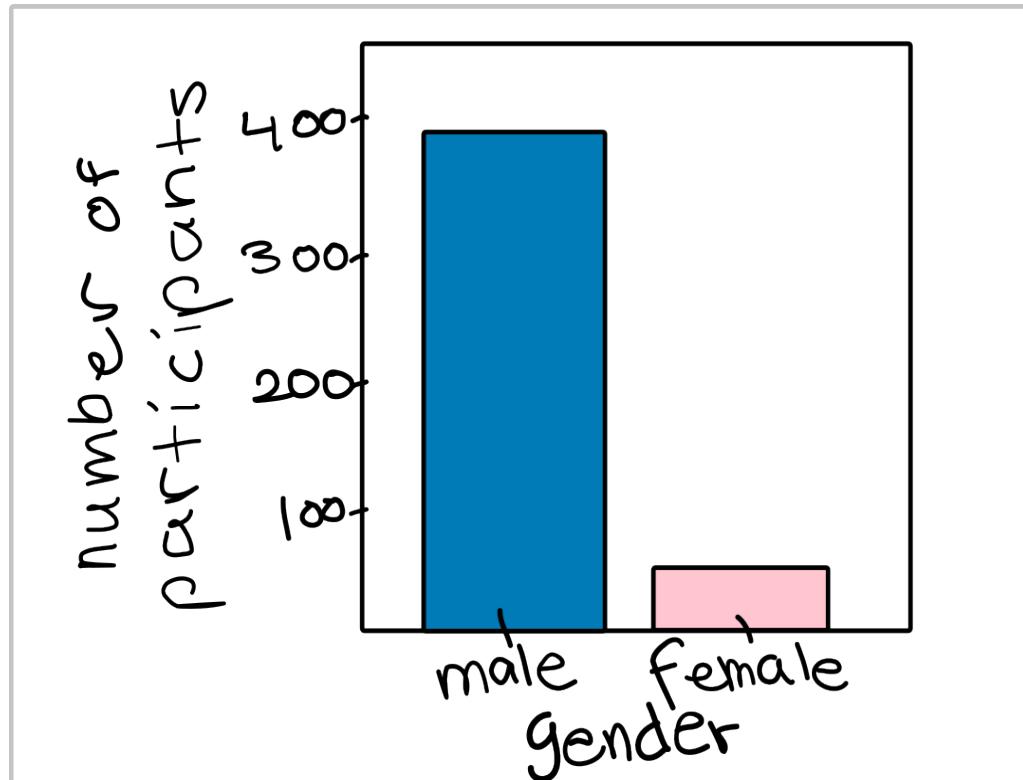
# Do we need to adapt it to the context?

- Academic presentation



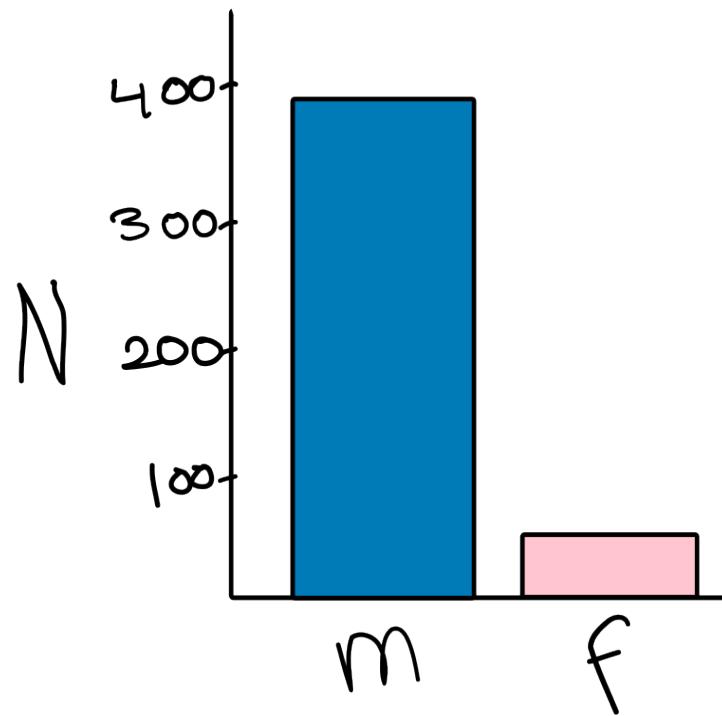
# Do we need to adapt it to the context?

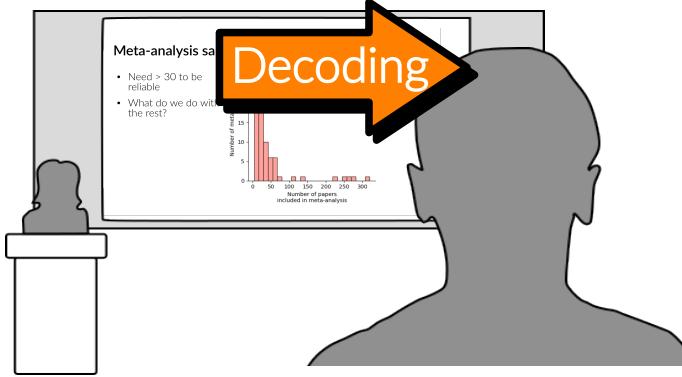
- Academic presentation



# Do we need to adapt it to the context?

- Academic presentation





To plan an **effective visualization**, we need to think about

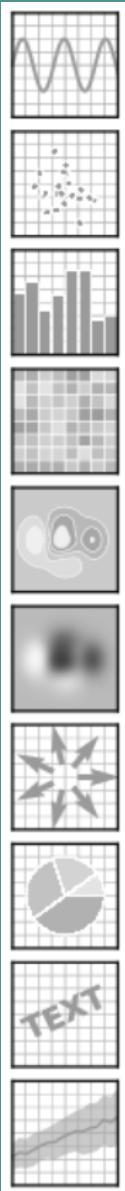
- **Message**
  - **What** we want to communicate
- **Perception**
  - **How best** to communicate it
- **Conventions**
  - **How** it's usually communicated
- **Context**
  - **Where** it will be seen

# The end of part 1

# Reference slides...

(For future reference)

# Choosing effective charts



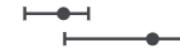
## Channels: Expressiveness Types and Effectiveness Ranks

### ⇒ **Magnitude Channels: Ordered Attributes**

Position on common scale



Position on unaligned scale



Length (1D size)



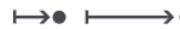
Tilt/angle



Area (2D size)



Depth (3D position)



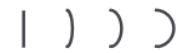
Color luminance



Color saturation



Curvature



Volume (3D size)



### ⇒ **Identity Channels: Categorical Attributes**

Spatial region



Color hue



Motion



Shape



Text

Fr  
Ca

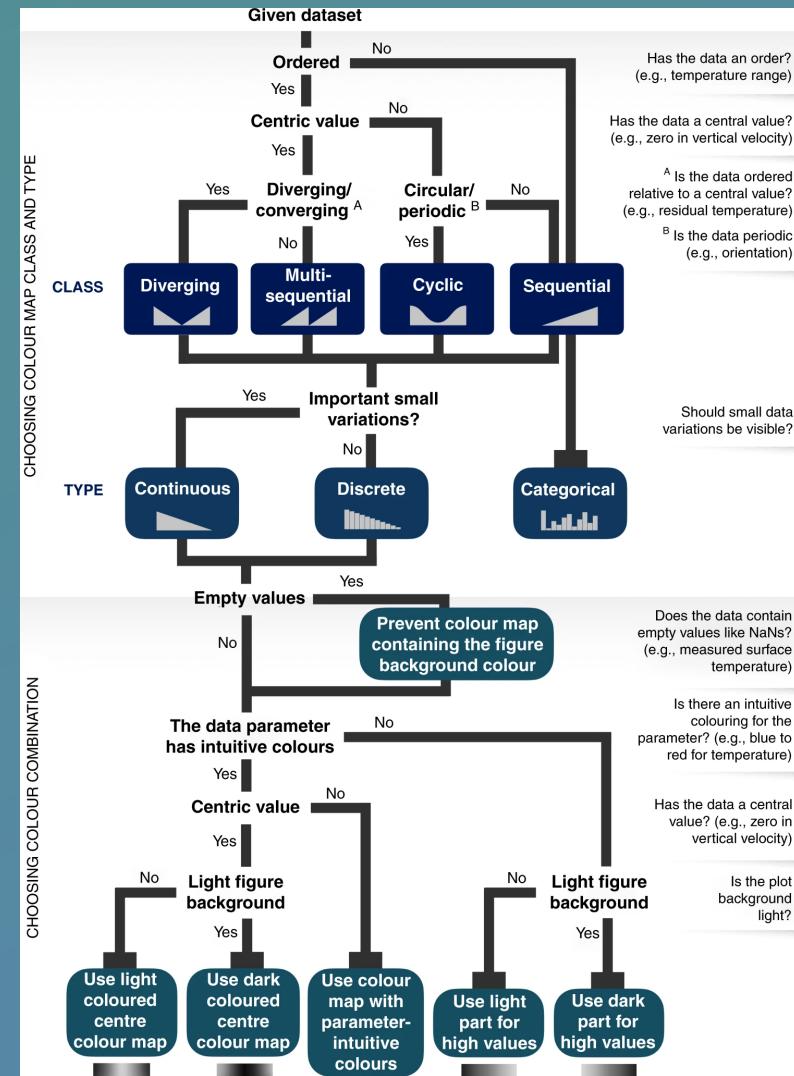
Canada Canada Canada  
France France France

[https://matplotlib.org/cheatsheets/\\_images/cheatsheets-1.png](https://matplotlib.org/cheatsheets/_images/cheatsheets-1.png)

Munzner, T. (2014). Visualization analysis and design. CRC press.

(For future reference)

# Choosing effective colormaps



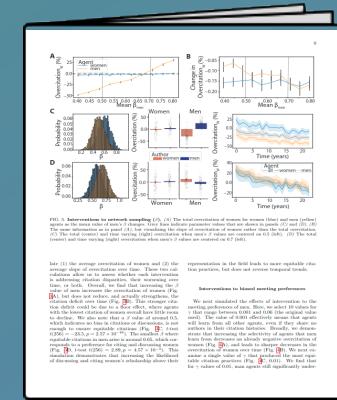
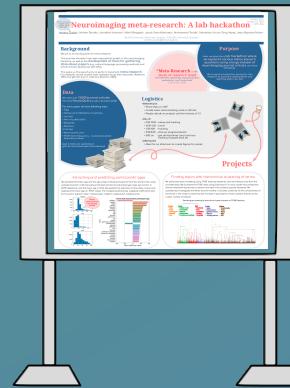
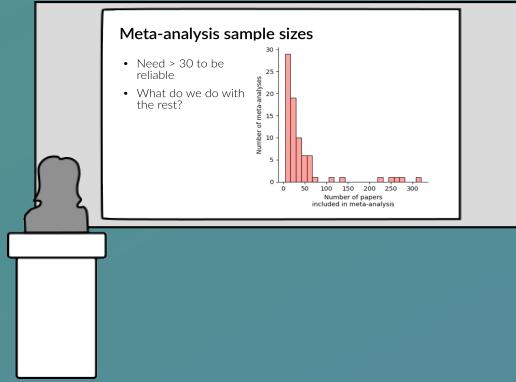
(For future reference)

# Examples of visualization conventions

- Culture
  - Pink is female
  - Time goes left to right
- Science
  - Rainbow colormaps are disliked
- Neuroscience
  - MRI in grayscale
  - DWI colors = directions

(For future reference)

# Contextual adjustments



Time to understand

Proximity to viz

Less

Text explanations

More

Self-explanatory

Visual complexity