

health expenditure % of GDP	-0.178	0.236	0.304		0.408	0.282	0.381	-0.310	-0.429	0.243	0.235	0.273	0.350	0.320	0.210	0.114
health expenditure per person	-0.378	0.737	0.753	0.408		0.179	0.880	-0.49	-0.485	0.509	0.796	0.778	0.750	0.714	0.620	0.268
education expenditure % of GDP	-0.092	0.254	0.418	0.282	0.179		0.379	-0.486	-0.439	0.231	0.34	0.314	0.337	0.396	0.124	0.335
education expenditure per person	-0.417	0.662	0.322	0.381	0.880	0.379		-0.431	-0.497	0.514	0.786	0.774	0.745	0.716	0.623	0.369
political rights score								0.947	-0.694	-0.545	-0.637	-0.677	-0.581	-0.479	-0.129	
civil liberties score								-0.71	-0.647	-0.684	-0.738	-0.627	-0.508	-0.125		
women MPs (% of all MPs)	-0.205	0.180	0.326	0.114	0.268	0.335	0.369	0.129	-0.125	0.104	0.269	0.230	0.173	0.221	0.101	

Session 2e

Color for Visualization

rule of law	-0.343	0.780	0.720	0.350	0.780	0.334	0.725	-0.677	-0.738	0.737		0.833	0.716	0.173		
control of corruption	-0.341	0.670	0.678	0.320	0.714	0.396	0.746	-0.581	-0.627	0.602	0.81	0.78	0.833		0.609	0.221
overall economic freedom score	-0.264	0.618	0.636	0.210	0.620	0.124	0.623	-0.479	-0.508	0.446	0.705	0.813	0.720	0.609		0.101
women MPs (% of all MPs)	-0.205	0.180	0.326	0.114	0.268	0.335	0.369	0.129	-0.125	0.104	0.269	0.230	0.173	0.221	0.101	

- education expenditure % of GDP
- education expenditure per person
- political stability & absence of violence
- regulatory quality
- rule of law
- control of corruption
- overall economic freedom score
- women MPs (% of all MPs)

Negatively correlated wrt

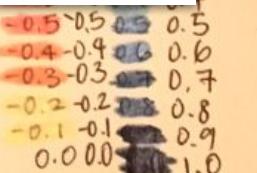
- GINI Index
- political rights score
- civil liberties score

effluent 5

* Pearson coefficients measure the strength and direction of the linear relationship between the two variables

-1 → perfect negative correlation
0 → no correlation

1 → perfect positive correlation



* a variable correlated with itself will always have a correlation coefficient of 1.

★ Data from 2017 and earlier ★



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Benjamin Bach

May 2022

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<https://datavis-online.github.io>

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Outline

What is color?

Color in visualization

Color Scales

Sequential, diverging, categorical scales

Rainbow color map

Color blindness

health expenditure % of GDP	-0.178	0.236	0.304		0.408	0.282	0.381	-0.310	-0.429	0.243	0.235	0.273	0.350	0.320	0.210	0.114
health expenditure per person	-0.378	0.737	0.753	0.408		0.179	0.880	-0.49	-0.485	0.509	0.796	0.778	0.750	0.714	0.620	0.268
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political rights score								0.947	-0.694	-0.545	-0.637	-0.677	-0.581	-0.479	-0.129	
civil liberties score								-0.71	-0.647	-0.684	-0.738	-0.627	-0.508	-0.125		
women MPs (% of all MPs)											0.615	0.759	0.662	0.446	0.104	
rule of law	-0.343	0.780	0.720	0.350	0.780	0.334	0.725	-0.677	-0.738	0.737		0.810	0.705	0.269		
control of corruption	-0.341	0.670	0.678	0.320	0.714	0.396	0.746	-0.581	-0.627	0.602	0.81		0.781	0.813	0.230	
overall economic freedom score	-0.264	0.618	0.636	0.210	0.620	0.124	0.623	-0.479	-0.508	0.446	0.705	0.813	0.720	0.609		0.101
women																
MPs (% of all MPs)	-0.205	0.180	0.326	0.114	0.268	0.335	0.369	0.129	-0.125	0.104	0.269	0.230	0.173	0.221	0.101	

- education expenditure % of GDP
- education expenditure per person
- political stability & absence of violence
- regulatory quality
- rule of law
- control of corruption
- overall economic freedom score
- women MPs (% of all MPs)

- Negatively correlated with -

- GINI Index
- political rights score
- civil liberties score

(Pearson Correlation coefficient 5)

-1.0	-1.0	0.0	0.0
-0.9	-0.9	0.1	0.1
-0.8	-0.8	0.2	0.2
-0.7	-0.7	0.3	0.3
-0.6	-0.6	0.4	0.4
-0.5	-0.5	0.5	0.5
-0.4	-0.4	0.6	0.6
-0.3	-0.3	0.7	0.7
-0.2	-0.2	0.8	0.8
-0.1	-0.1	0.9	0.9
0.0	0.0	1.0	1.0

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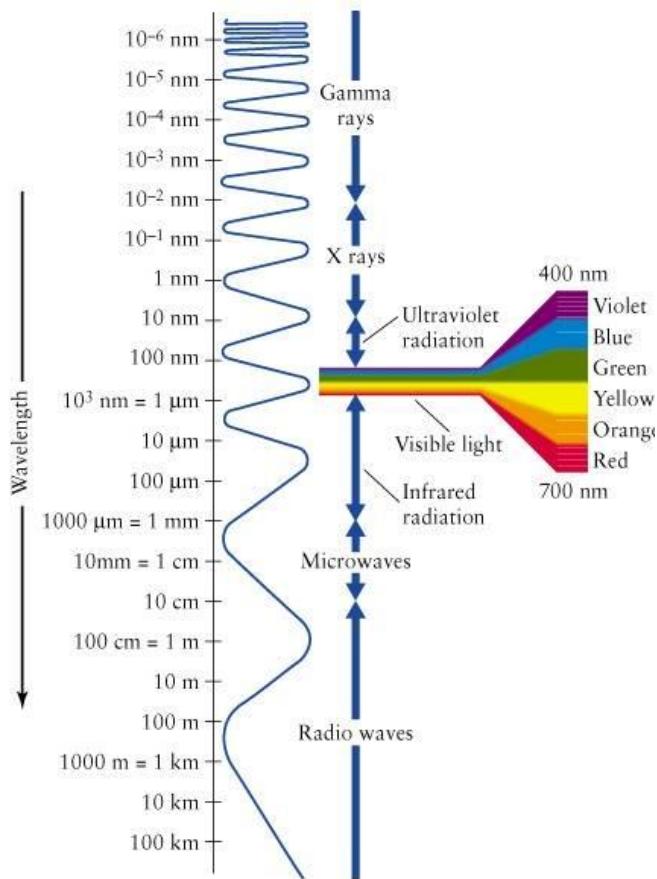
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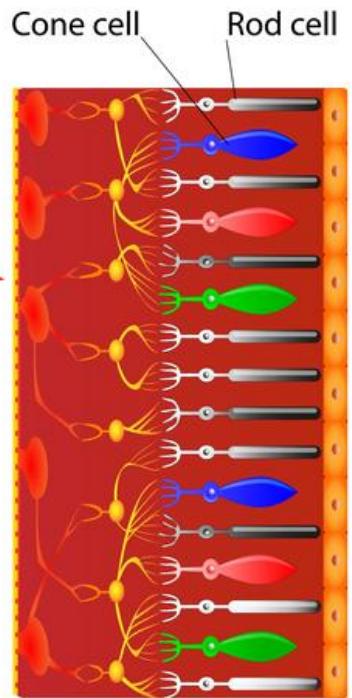
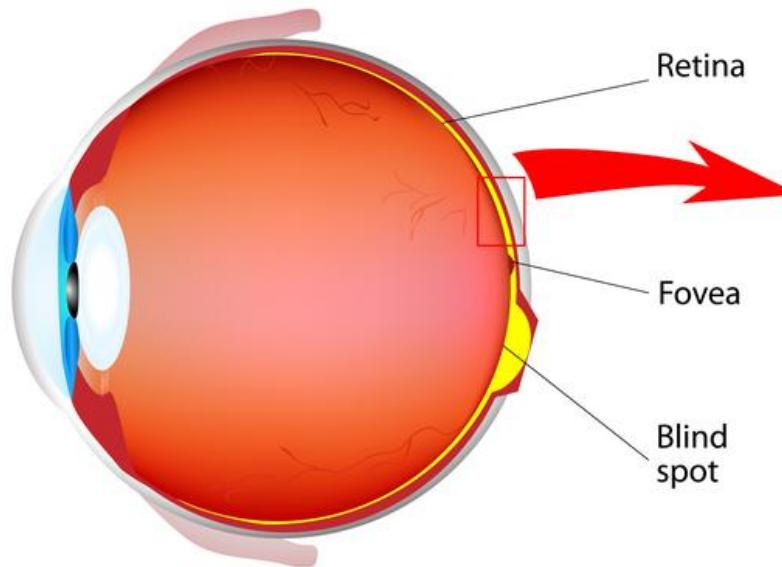
<https://datavis-online.github.io>

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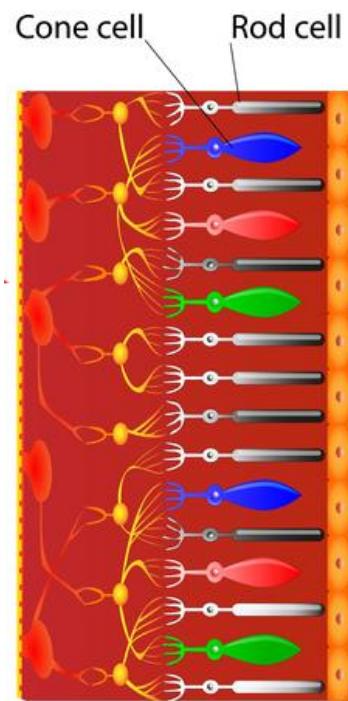
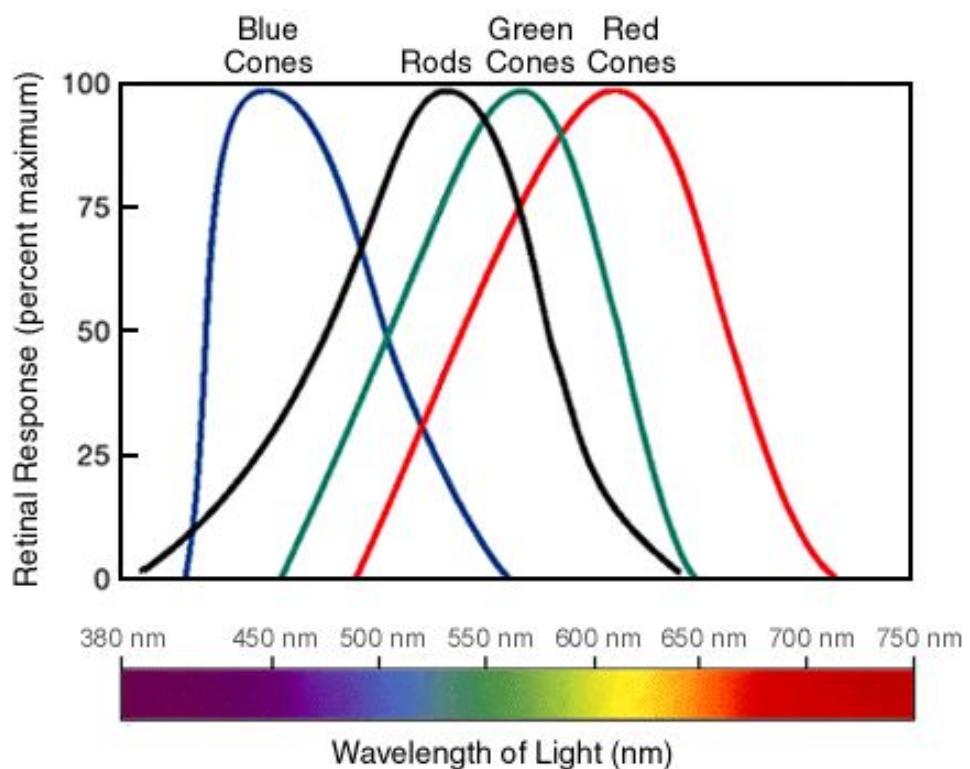
Photoreceptor cell



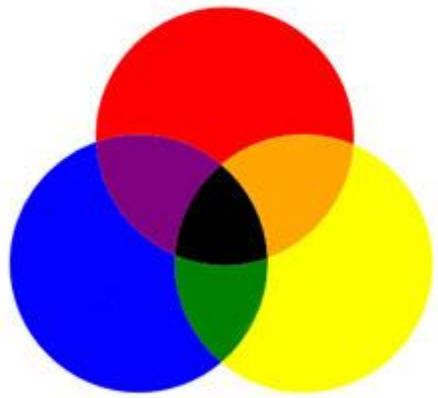
400-700nm



**~120 million rods
~6 million cones**



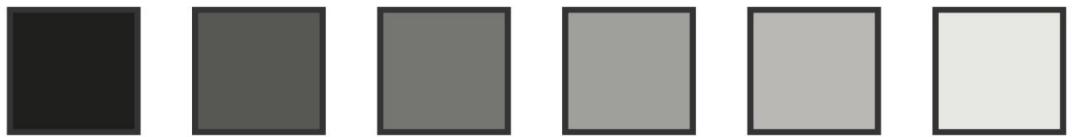
Color Models



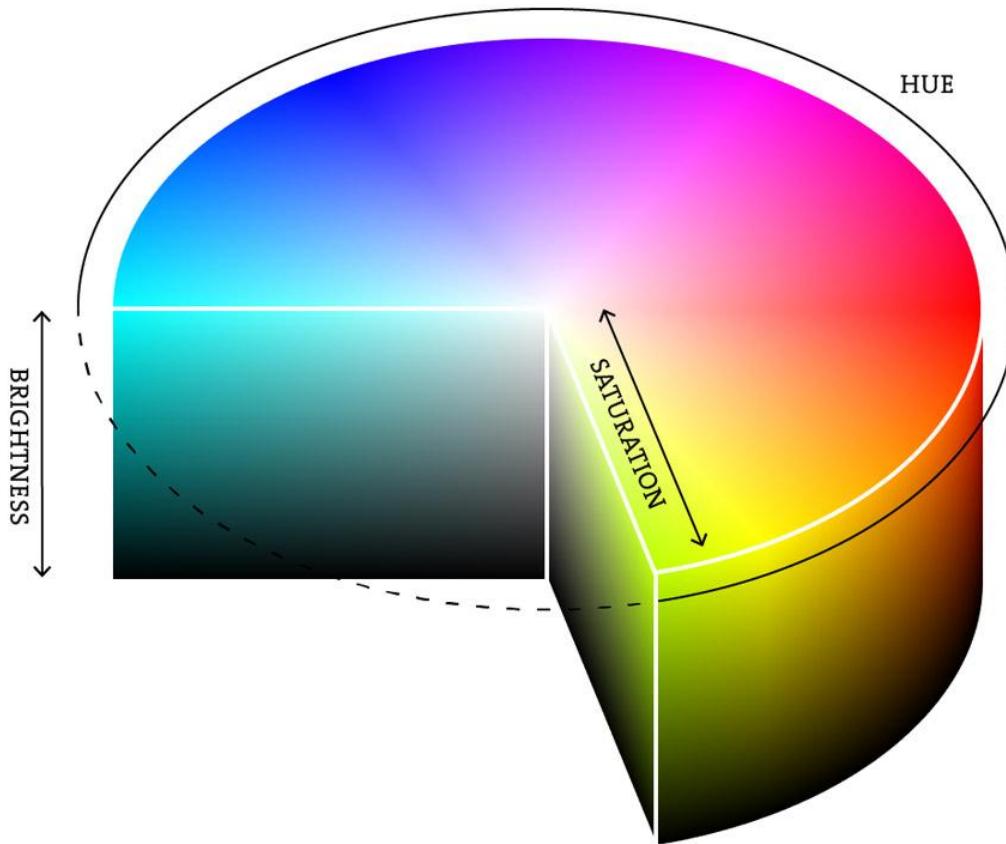
RYB

What is color?

Luminance



HSB Model: Hue, Saturation, Brightness

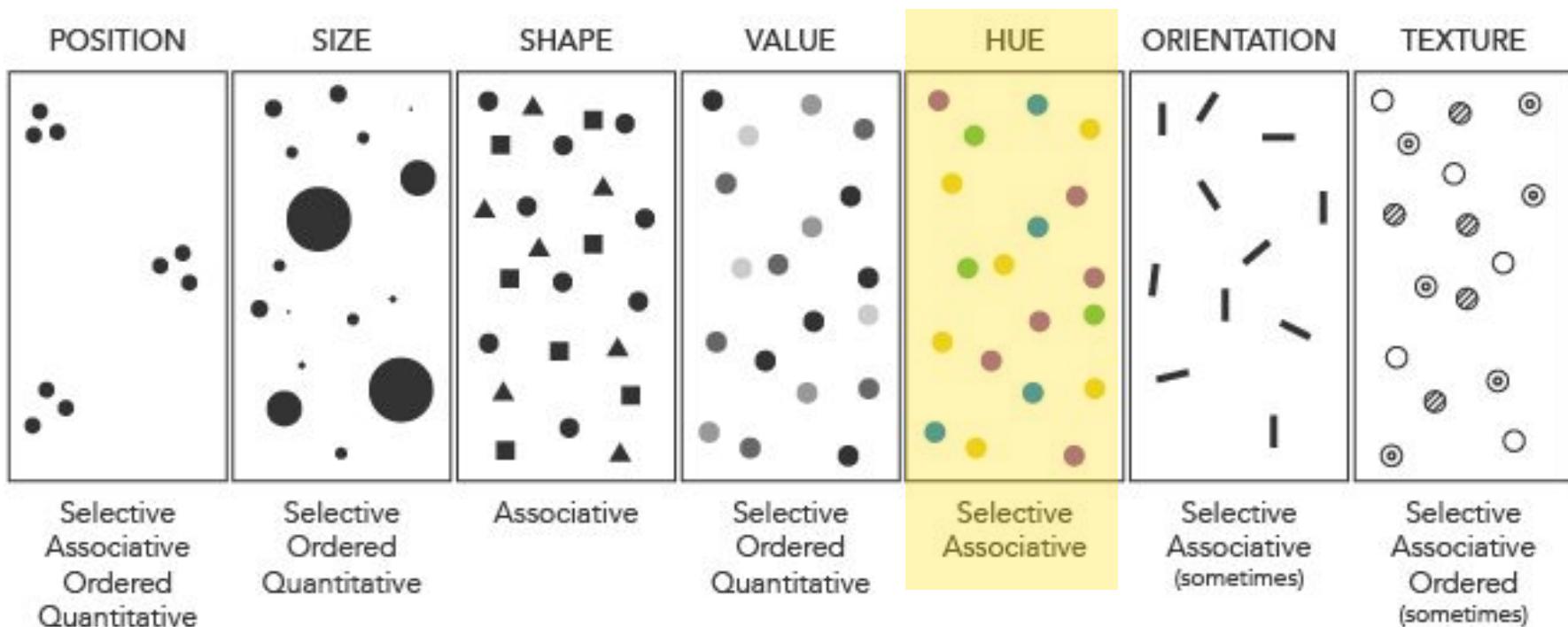


Color = (Brightness/Lightness, Saturation, Hue)

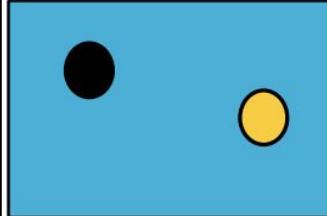
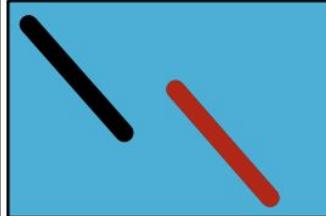
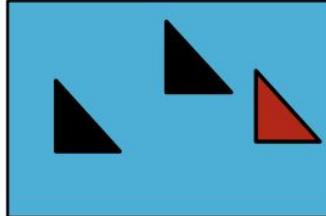
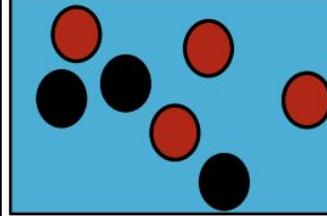
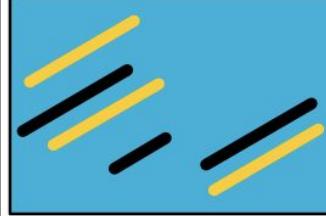
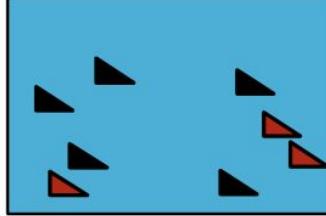
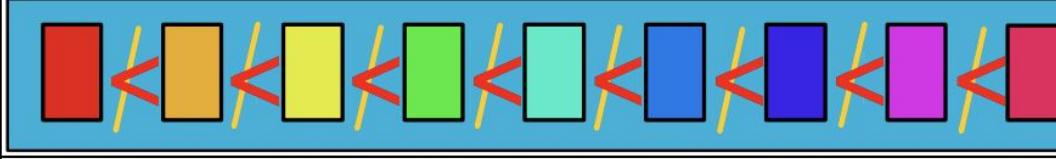
HSB Color Picker

Visual Variables

Bertin's Visual Variables



Visual Variable: Colour

	selective			
	associative			
	quantitative			
	order			
	length		<ul style="list-style-type: none"> • theoretically infinite but practically limited • association and selection ~ < 7 and distinction ~ 10 	

Quantitative

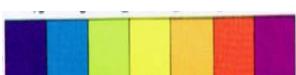
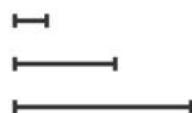
Position
Length
Angle
Slope
Area
Volume
Density
Color Saturation
Color Hue
Texture
Connection
Containment
Shape

Ordinal

Position
Density
Color Saturation
Color Hue
Texture
Connection
Containment
Length
Angle
Slope
Area
Volume
Shape

Nominal

Position
Color Hue
Texture
Connection
Containment
Density
Color Saturation
Shape
Length
Angle
Slope
Area
Volume



health expenditure % of GDP	-0.178	0.236	0.304		0.408	0.282	0.381	-0.310	-0.429	0.243	0.235	0.273	0.350	0.320	0.210	0.114	
health expenditure per person	-0.378	0.737	0.753	0.408		0.179	0.880	-0.49	-0.485	0.509	0.796	0.778	0.750	0.714	0.620	0.268	
education expenditure % of GDP	-0.092	0.254	0.418	0.282	0.179		0.379	-0.486	-0.439	0.231	0.34	0.314	0.337	0.396	0.124	0.335	
education expenditure per person	-0.417	0.662	0.322	0.381	0.880	0.379		-0.431	-0.497	0.514	0.786	0.774	0.745	0.716	0.623	0.369	
political rights score								0.947	-0.694	-0.545	-0.637	-0.677	-0.580	-0.479	-0.129		
civil liberties score								-0.71	-0.647	-0.684	-0.738	-0.627	-0.508	-0.125			
women MPs (% of all MPs)								0.706	0.645	0.759	0.662	0.446	0.104				
GINI Index										0.793	0.810	0.705	0.269				
political stability & absence of violence										0.781	0.813	0.230					
regulatory quality											0.833	0.716	0.173				
rule of law	-0.343	0.780	0.730	0.350	0.780	0.334	0.725	-0.677	-0.738	0.737							
control of corruption	-0.341	0.670	0.678	0.320	0.714	0.396	0.746	-0.581	-0.627	0.602	0.81						
overall economic freedom score	-0.264	0.618	0.636	0.210	0.620	0.124	0.623	-0.479	-0.508	0.446	0.705	0.813	0.720	0.609		0.101	
women MPs (% of all MPs)	-0.205	0.180	0.326	0.114	0.268	0.335	0.369	0.129	-0.125	0.104	0.269	0.230	0.173	0.221	0.101		

- education expenditure % of GDP
- education expenditure per person
- political stability & absence of violence
- regulatory quality
- rule of law
- control of corruption
- overall economic freedom score
- women MPs (% of all MPs)

- Negatively correlated with -

- GINI Index
- political rights score
- civil liberties score

(Pearson Correlation coefficient 5)

-1.0	-1.0	0.0	0.0
-0.9	-0.9	0.1	0.1
-0.8	-0.8	0.2	0.2
-0.7	-0.7	0.3	0.3
-0.6	-0.6	0.4	0.4
-0.5	-0.5	0.5	0.5
-0.4	-0.4	0.6	0.6
-0.3	-0.3	0.7	0.7
-0.2	-0.2	0.8	0.8
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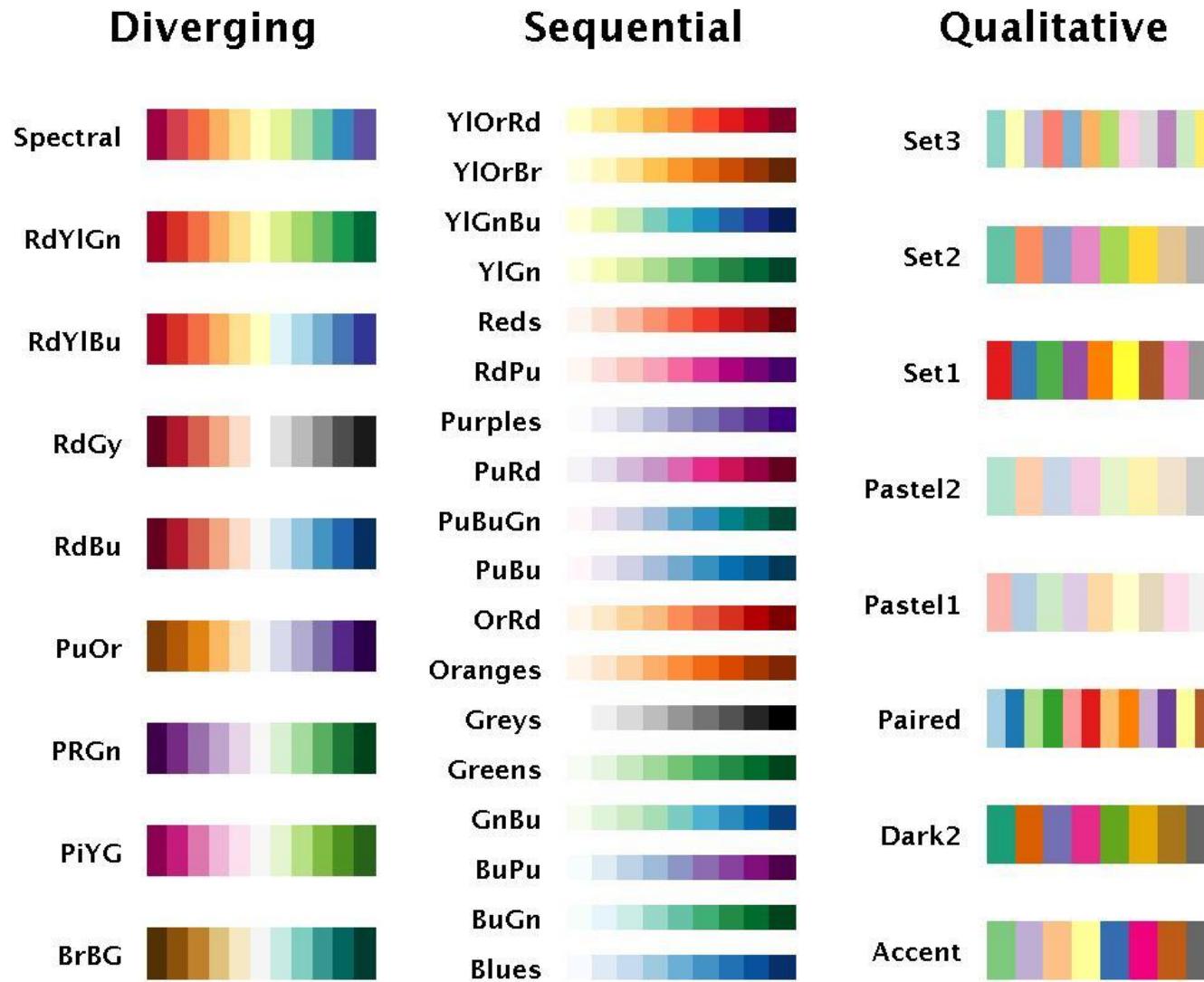
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<https://datavis-online.github.io>

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More examples of color scales (ColorBrewer)



Binary



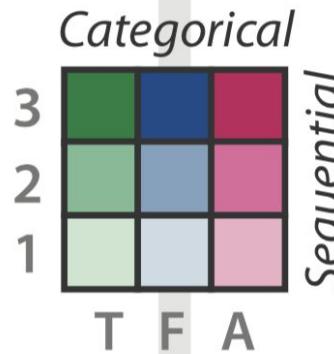
Categorical



Binary



Categorical

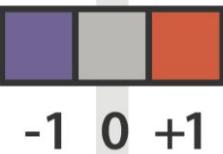


Sequential

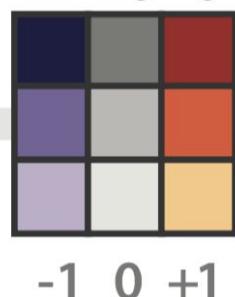


Sequential

Diverging



Diverging



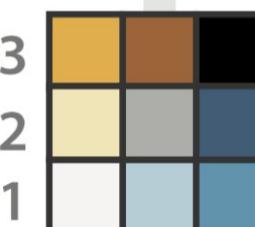
Sequential



Diverging

-1 0 +1

Sequential



Sequential

25 50 75

Colorbrewer.org

Number of data classes: 9 

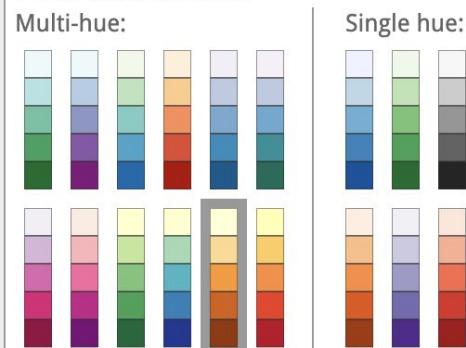
[how to use](#) | [updates](#) | [downloads](#) | [credits](#)

COLORBREWER 2.0

color advice for cartography

Nature of your data:

Pick a color scheme:



Only show:

- colorblind safe
 - print friendly
 - photocopy safe

Context:

- roads
 - cities
 - borders

Background:

- solid color
 - terrain

color transparency

9-class YIOrBr



HEX

EXPORT

#ffffe5

#fff7bc

#f0e320

#IEE59

#fec44f

#fe992b

#e-701

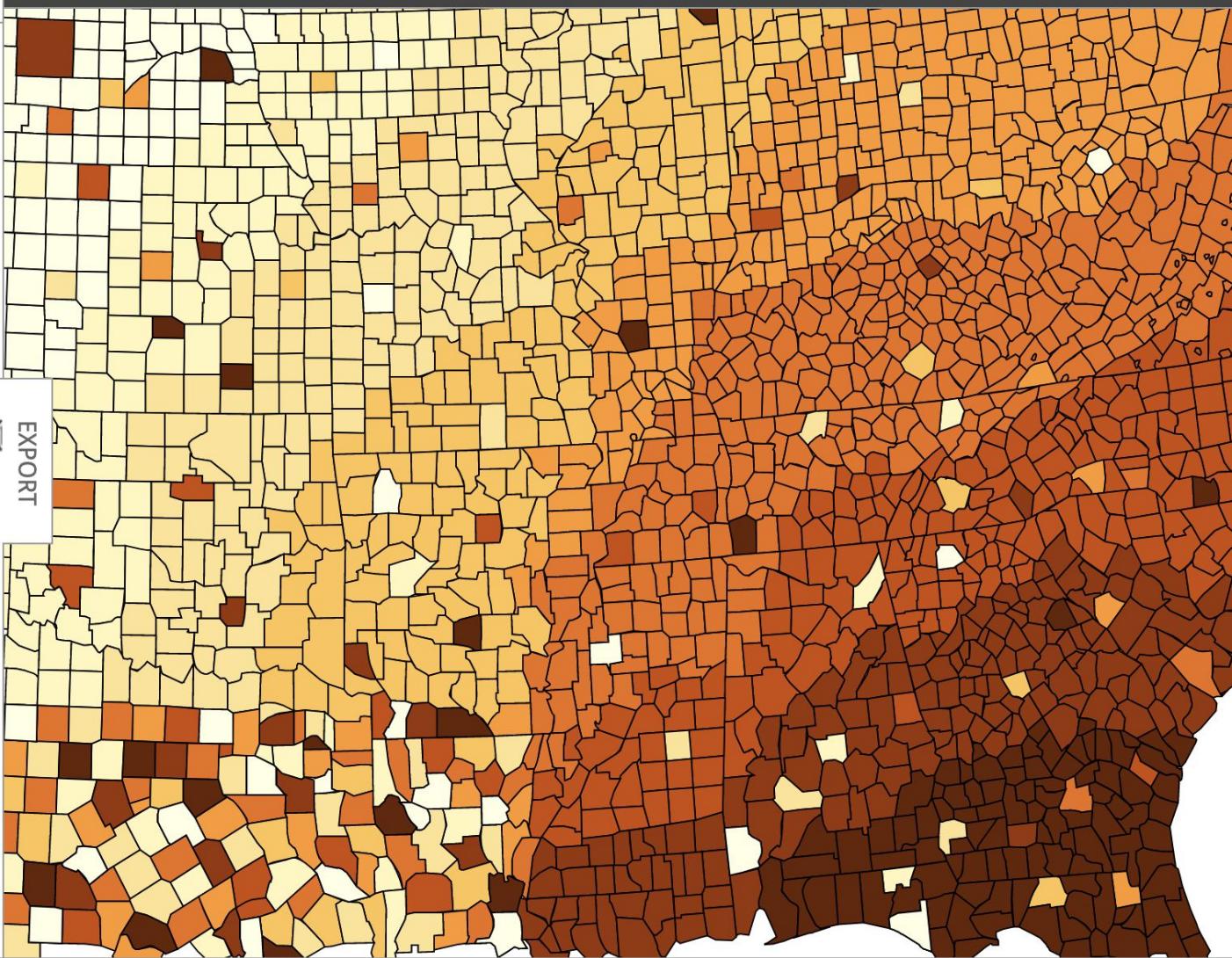
#ECL701

#cc4c02

#99340

166250

#66250



health expenditure % of GDP	-0.178	0.236	0.304		0.408	0.282	0.381	-0.310	-0.429	0.243	0.235	0.273	0.350	0.320	0.210	0.114
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political rights score								0.947	-0.694	-0.545	-0.637	-0.677	-0.581	-0.479	-0.129	
civil liberties score								-0.71	-0.647	-0.684	-0.738	-0.627	-0.508	-0.125		
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Session 2e

Sequential Scales

- education expenditure % of GDP
- education expenditure per person
- political stability & absence of violence
- regulatory quality
- rule of law
- control of corruption
- overall economic freedom score
- women MPs (% of all MPs)

- Negatively correlated with -

- GINI Index
- political rights score
- civil liberties score

(Pearson Correlation coefficient 5)

-1.0	-1.0	0.0	0.0
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-0.6	-0.6	0.4	0.4
-0.5	-0.5	0.5	0.5
-0.4	-0.4	0.6	0.6
-0.3	-0.3	0.7	0.7
-0.2	-0.2	0.8	0.8
-0.1	-0.1	0.9	0.9
0.0	0.0	1.0	1.0

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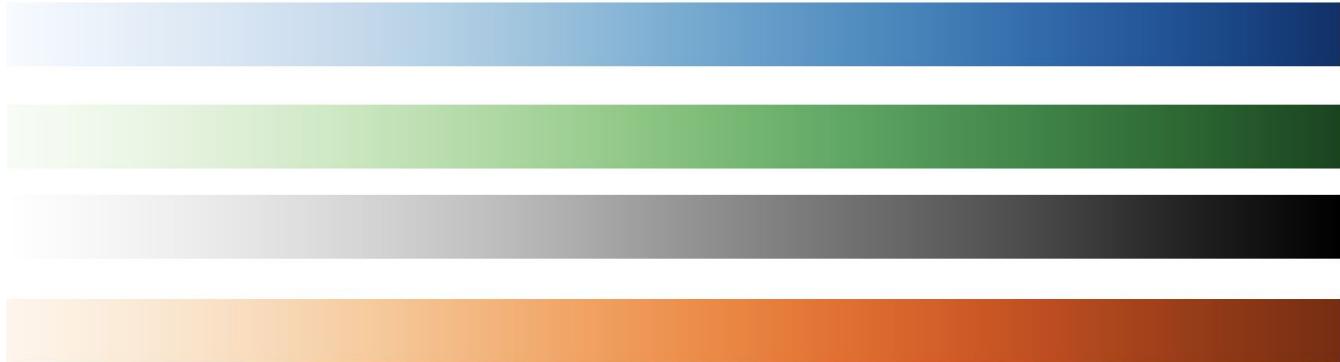
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More examples of color scales (ColorBrewer)

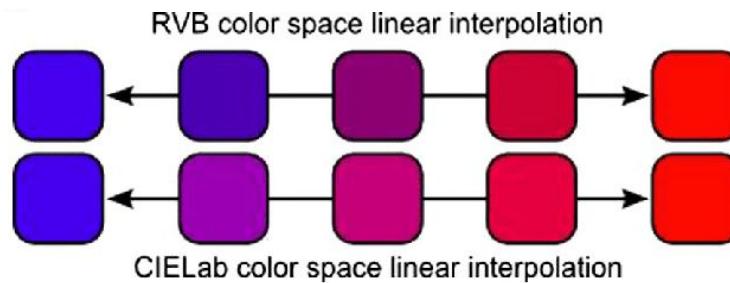


Sequential color scales

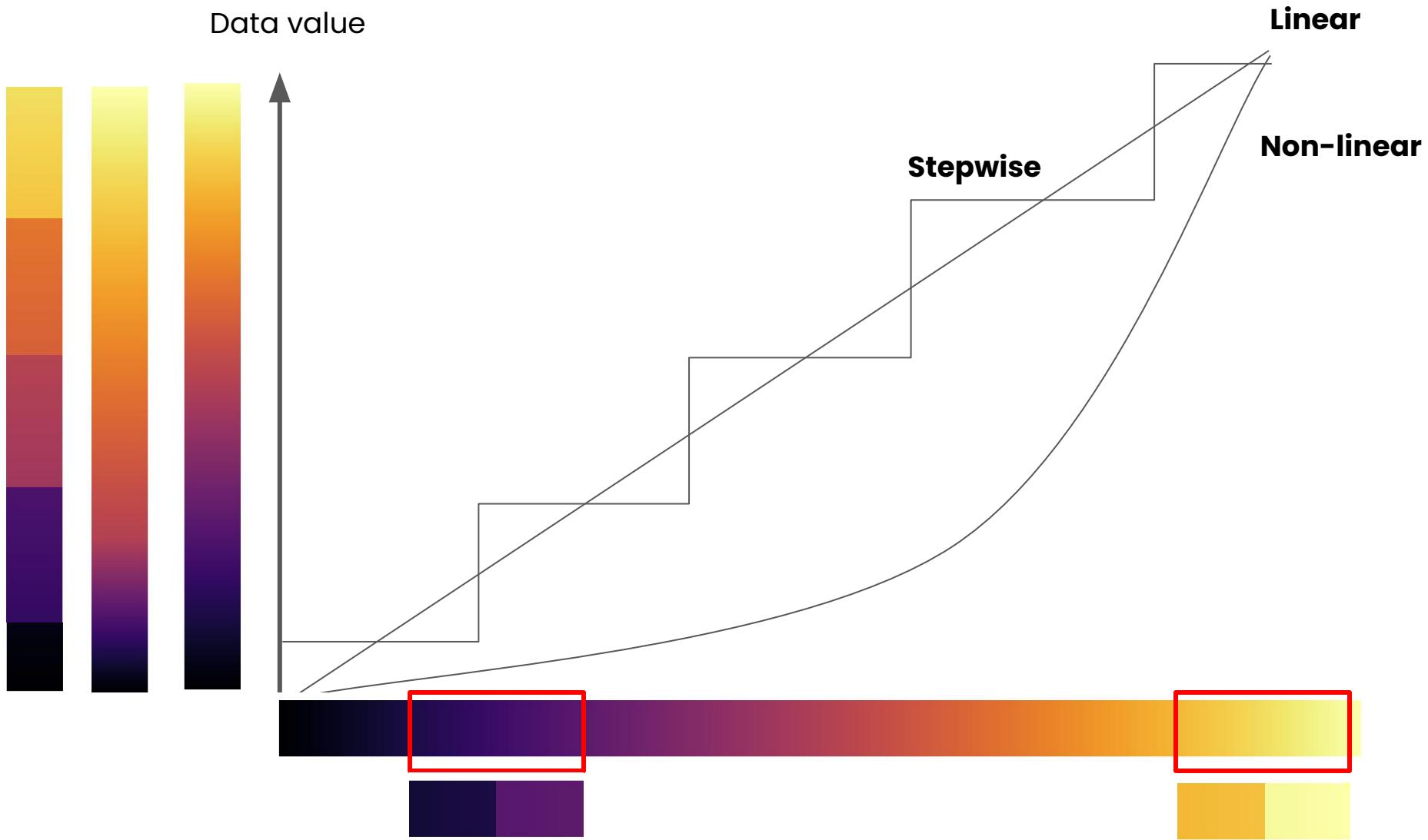
Single hue:

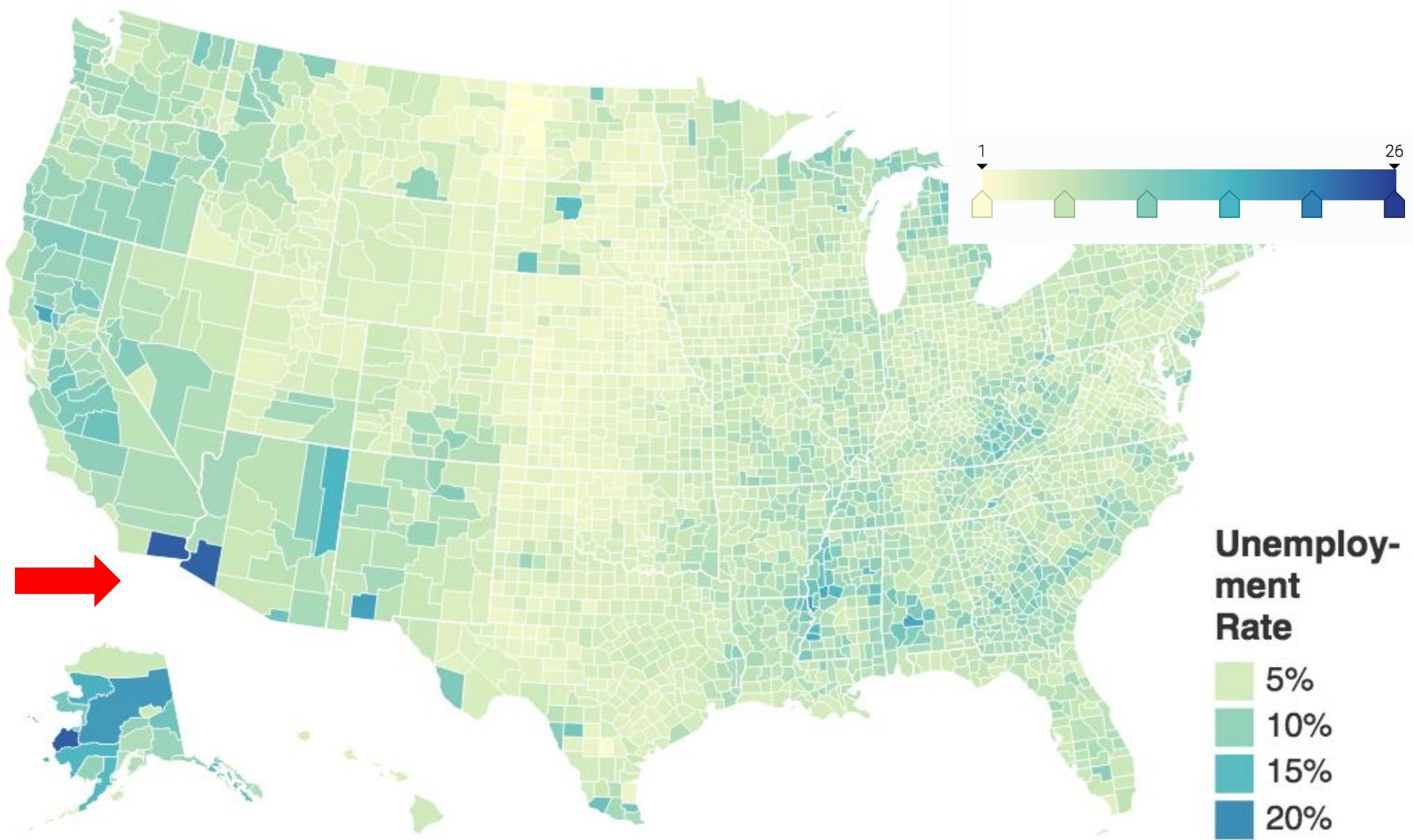


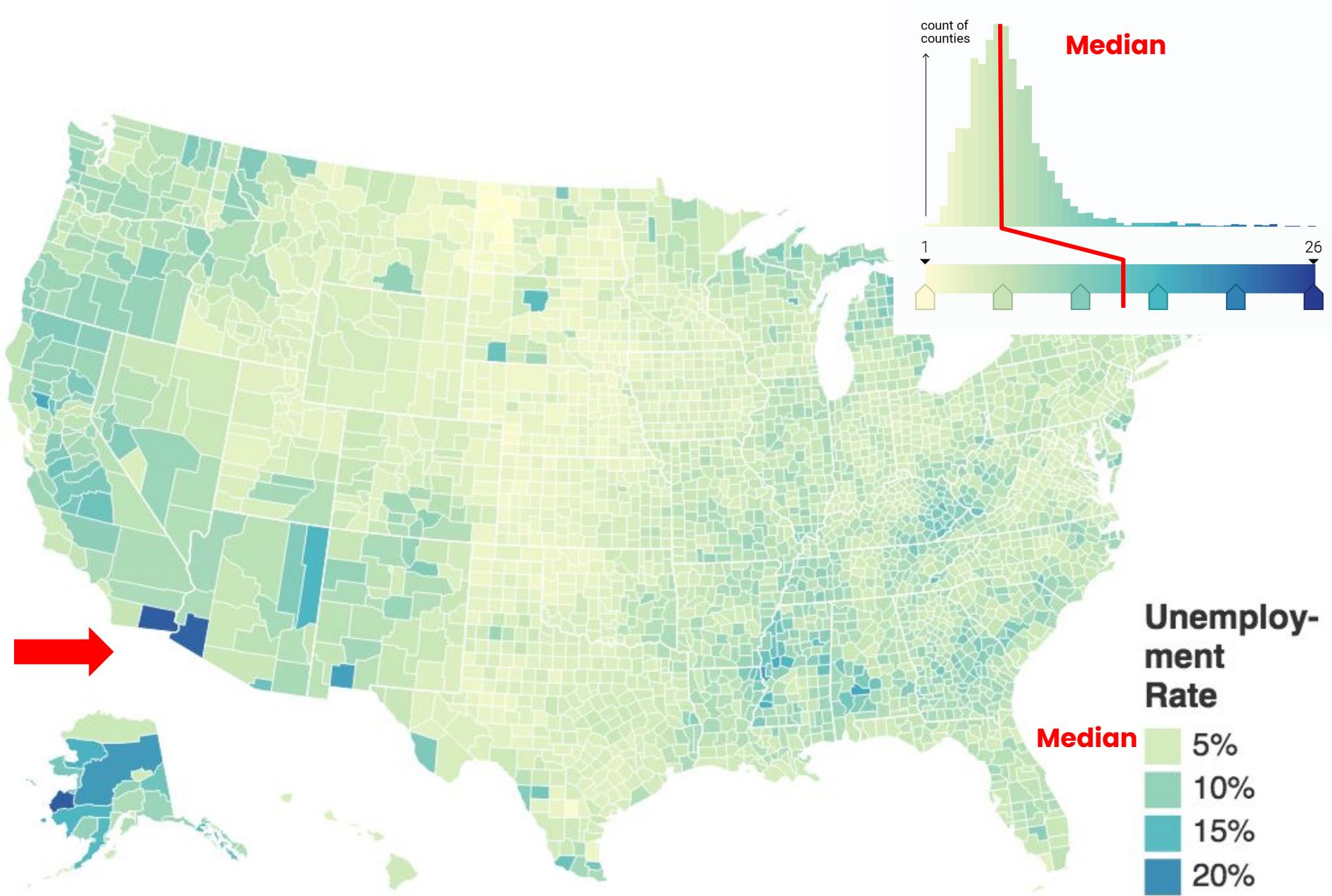
Multi hue:

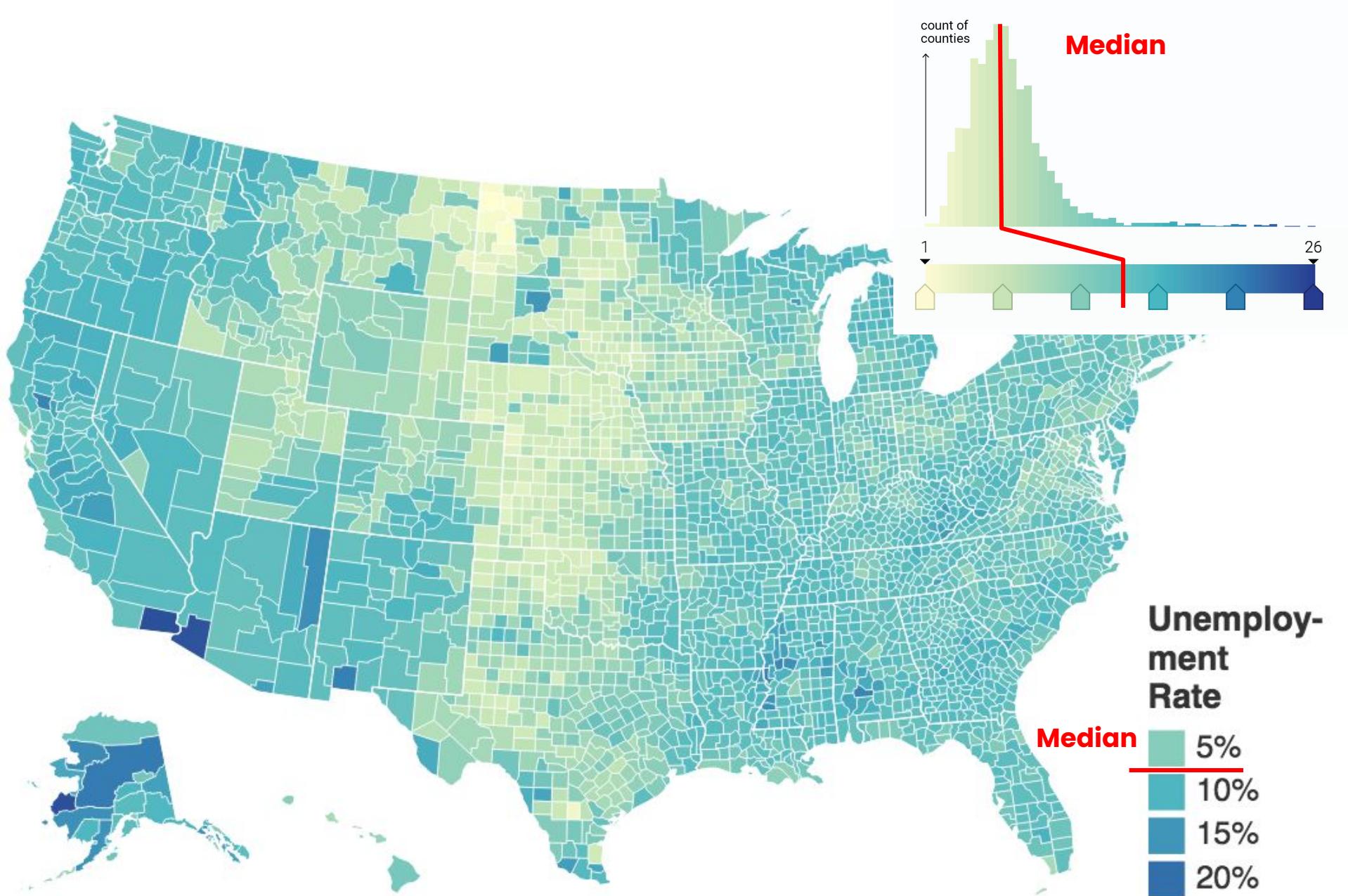


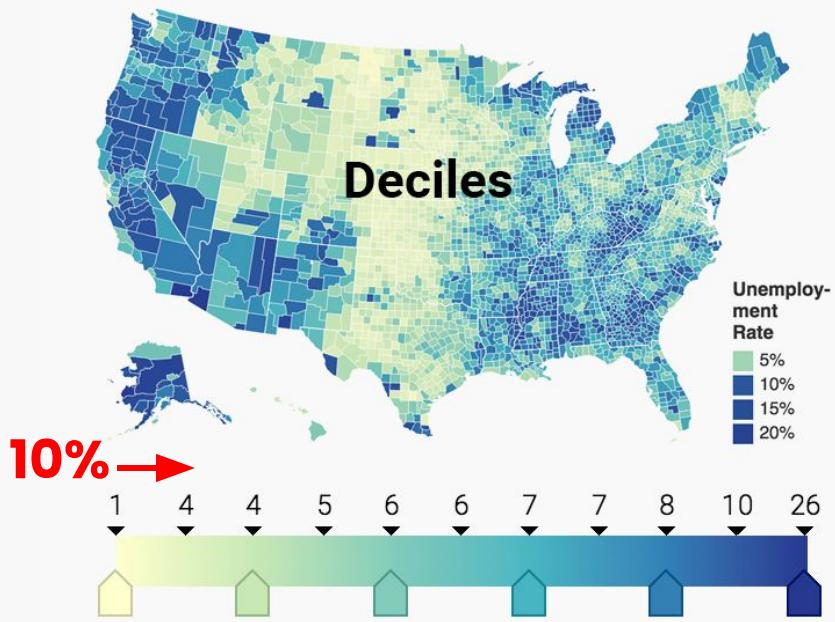
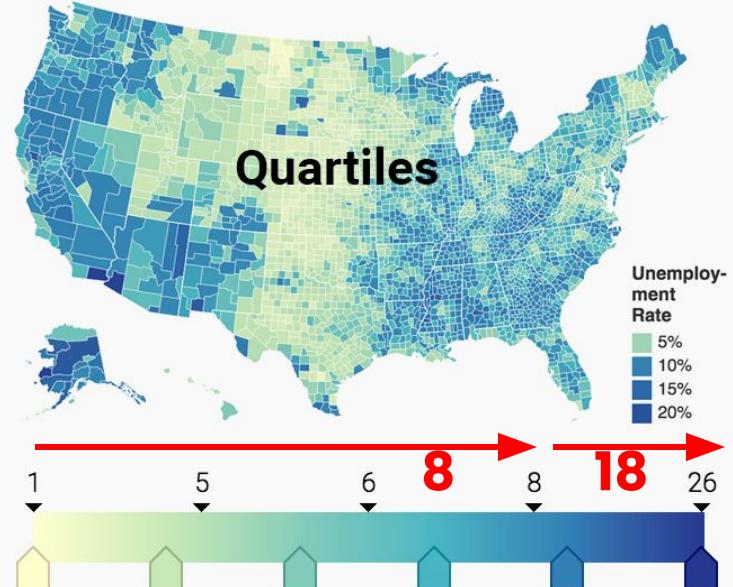
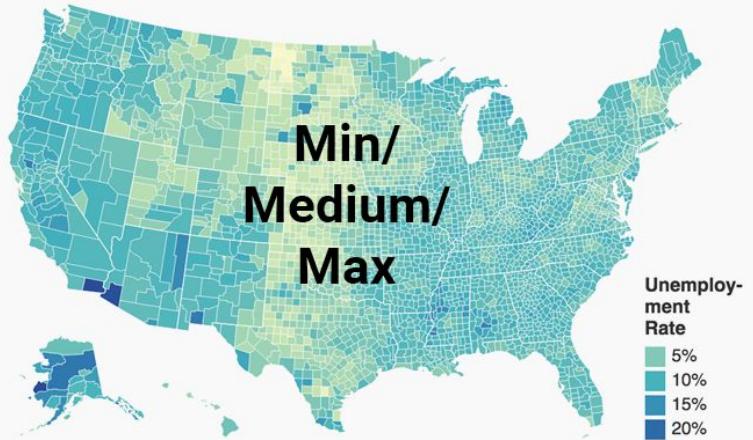
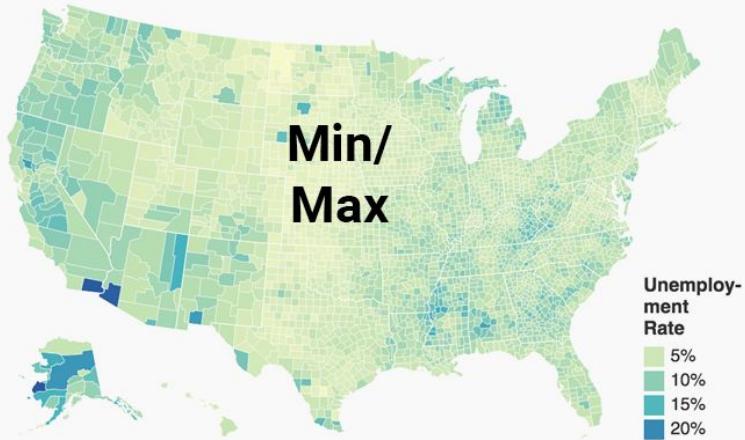
Mapping color scales

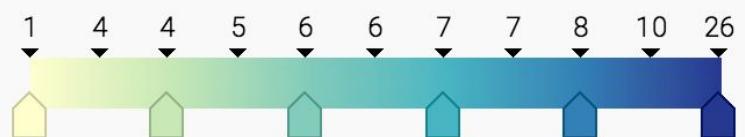
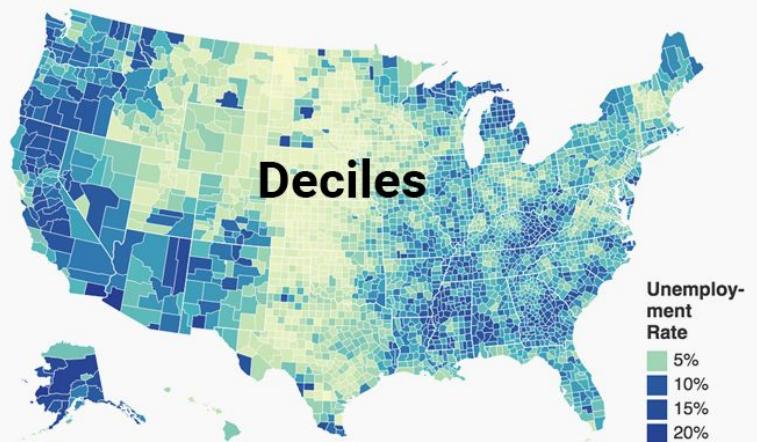


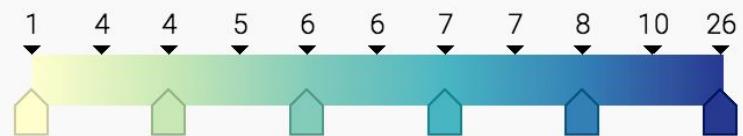
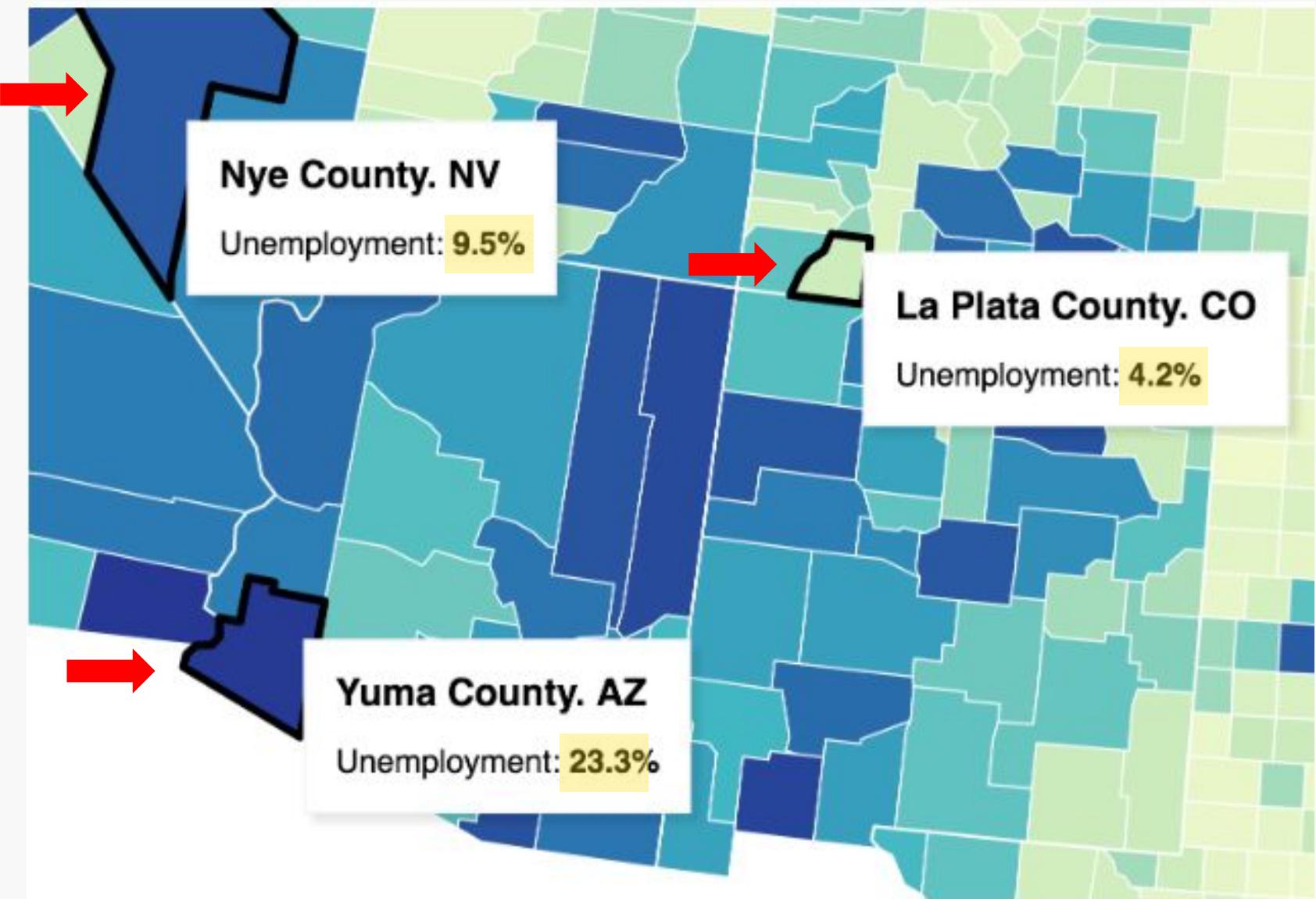


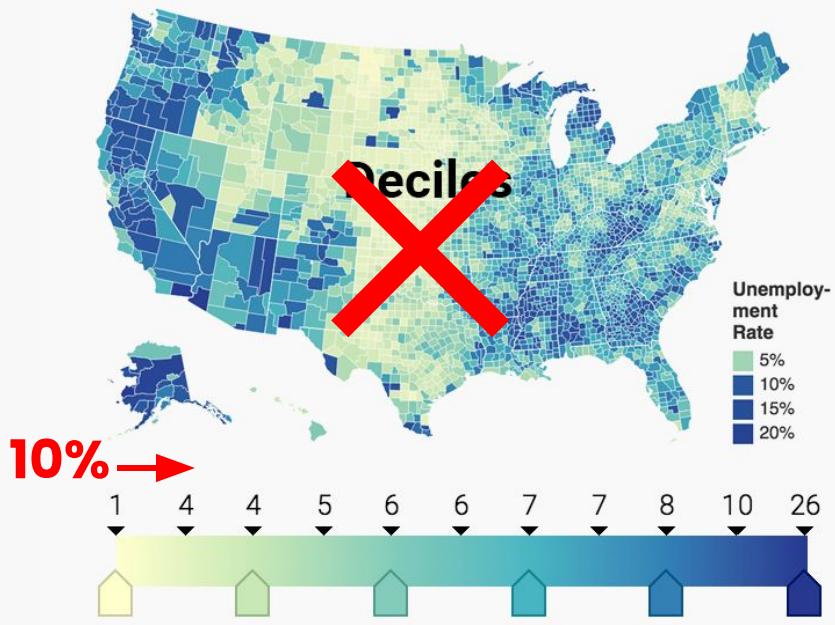
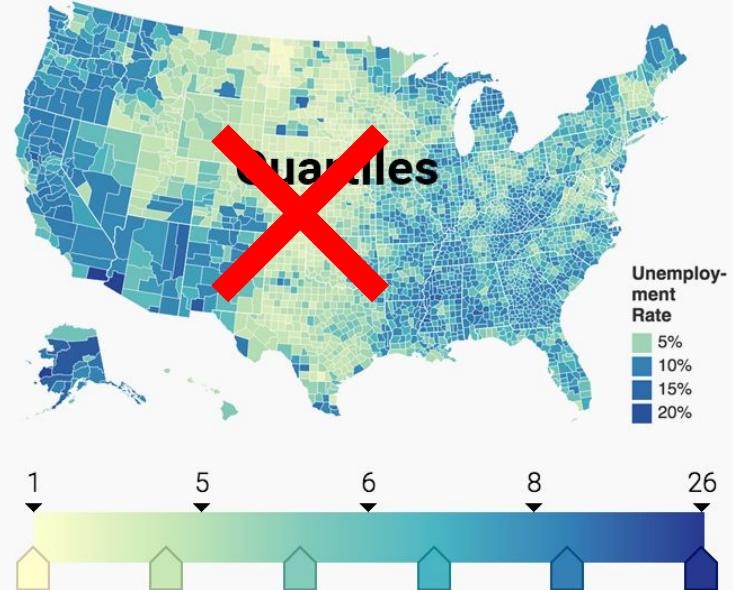
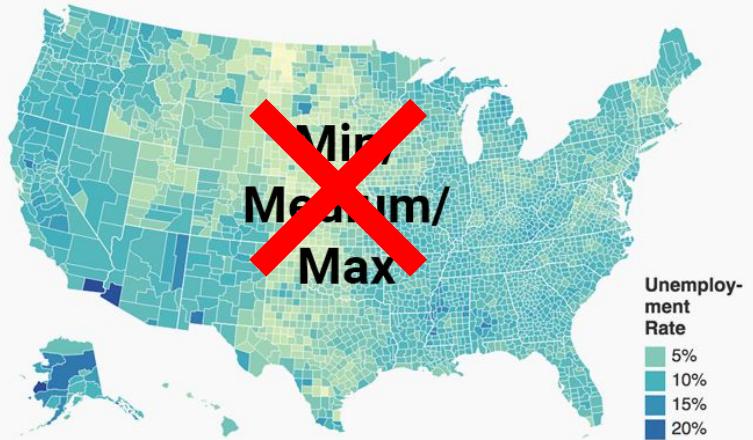
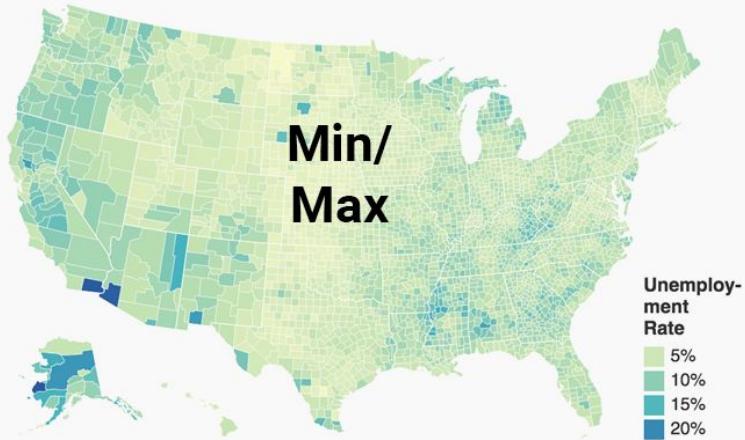












health expenditure % of GDP	-0.178	0.236	0.304		0.408	0.282	0.381	-0.310	-0.429	0.243	0.235	0.273	0.350	0.320	0.210	0.114
health expenditure per person	-0.378	0.737	0.753	0.408		0.179	0.880	-0.49	-0.485	0.509	0.796	0.778	0.750	0.714	0.620	0.268
education expenditure % of GDP	-0.092	0.254	0.418	0.282	0.179		0.379	-0.486	-0.439	0.231	0.34	0.314	0.337	0.396	0.124	0.335
education expenditure per person	-0.417	0.662	0.322	0.381	0.880	0.379		-0.431	-0.497	0.514	0.786	0.774	0.745	0.716	0.623	0.369
political rights score								0.947	-0.694	-0.545	-0.637	-0.677	-0.581	-0.479	-0.129	
rule of law								-0.71	-0.647	-0.684	-0.738	-0.627	-0.508	-0.125		
civil liberties score								-0.701	-0.675	-0.759	-0.662	-0.446	-0.104			
overall economic freedom score								-0.755	-0.720	-0.813	-0.720	-0.609	-0.101			
women MPs (% of all MPs)	-0.205	0.180	0.326	0.114	0.268	0.385	0.369	0.129	-0.125	0.104	0.269	0.230	0.173	0.221	0.101	

Session 2e

Diverging Scales

- education expenditure % of GDP
- education expenditure per person
- political stability & absence of violence
- regulatory quality
- rule of law
- control of corruption
- overall economic freedom score
- women MPs (% of all MPs)

- Negatively correlated wrt -

- GINI Index
- political rights score
- civil liberties score

(Pearson Correlation coefficient 5)

-1.0	-1.0	0.0	0.0
-0.9	-0.9	0.1	0.1
-0.8	-0.8	0.2	0.2
-0.7	-0.7	0.3	0.3
-0.6	-0.6	0.4	0.4
-0.5	-0.5	0.5	0.5
-0.4	-0.4	0.6	0.6
-0.3	-0.3	0.7	0.7
-0.2	-0.2	0.8	0.8
-0.1	-0.1	0.9	0.9
0.0	0.0	1.0	1.0

* Pearson coefficients measure the strength and direction of the linear relationship between the two variables

-1 → perfect negative correlation
0 → no correlation

1 → perfect positive correlation

* a variable correlated with itself will always have a correlation coefficient of 1.

★ Data from 2017 and earlier ★



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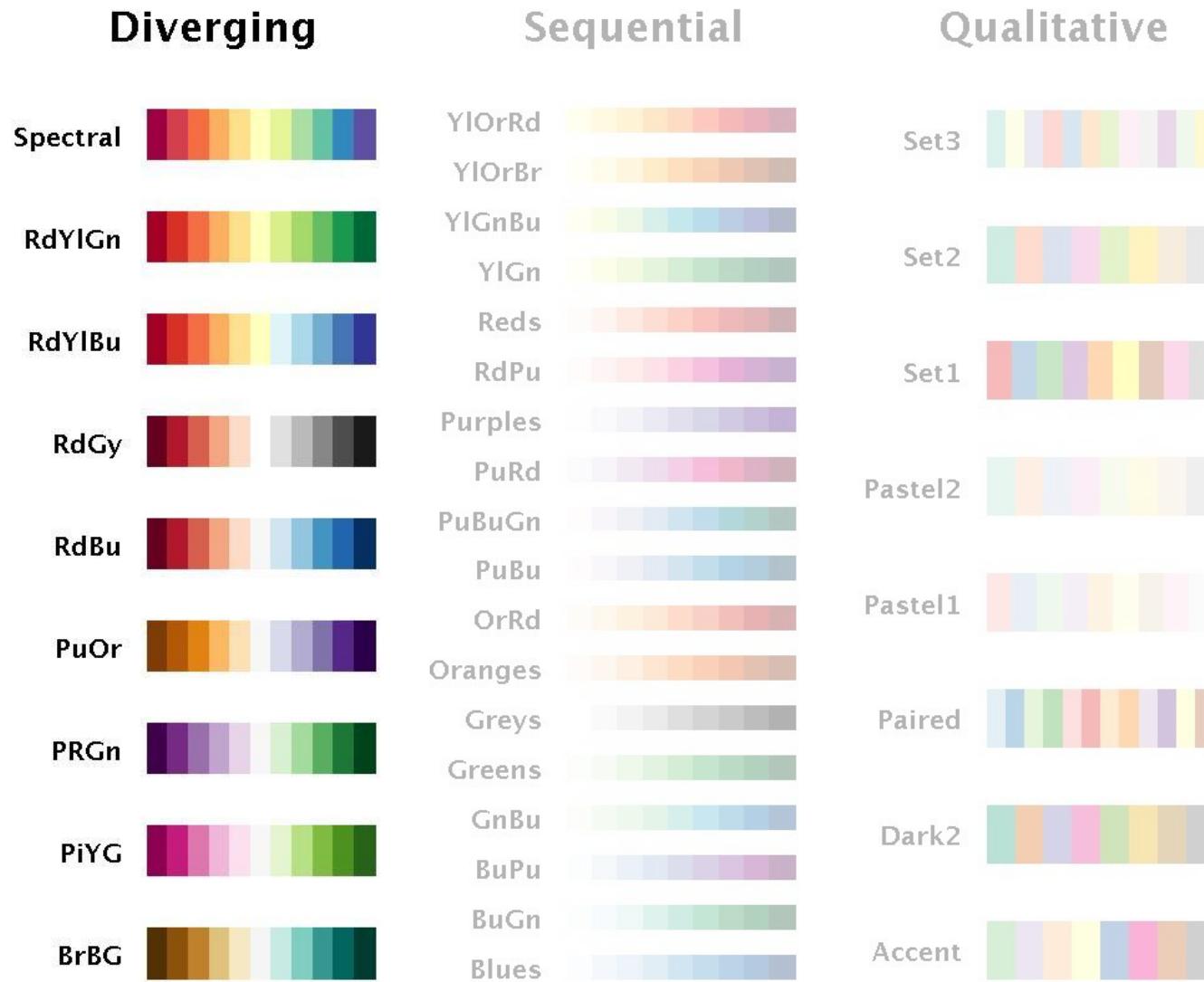
May 2022

<http://benjbach.me>

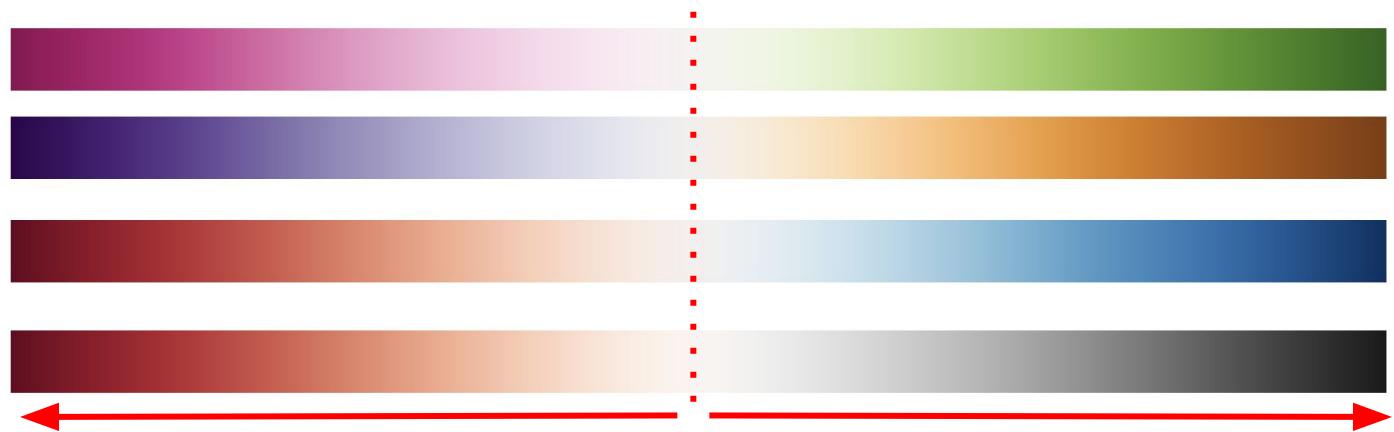
<https://datavis-online.github.io>

-- Not for external use --

More examples of color scales (ColorBrewer)



Diverging color scale



Multi hue:

d3.interpolateViridis(t) <>



d3.interpolateInferno(t) <>

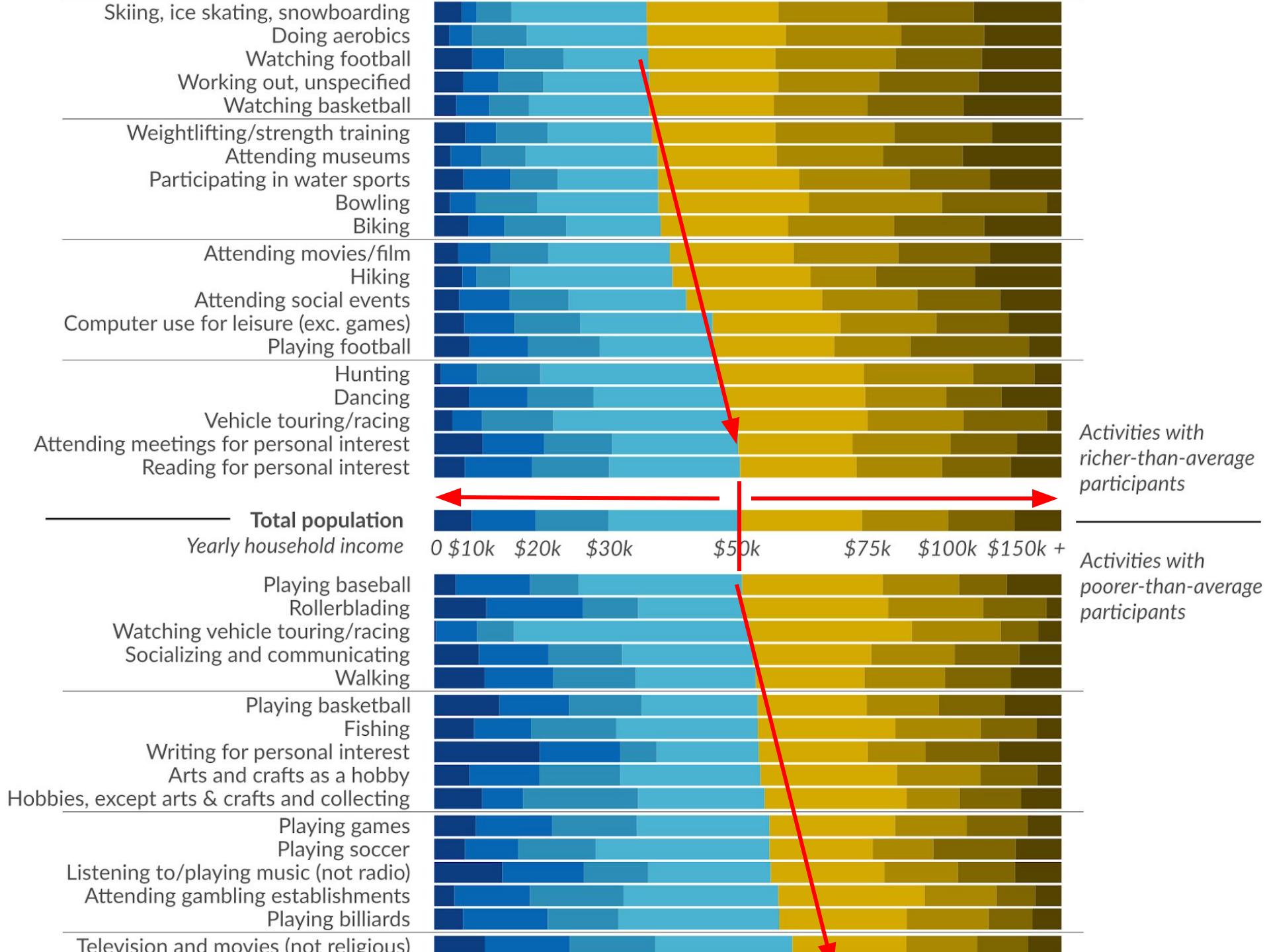


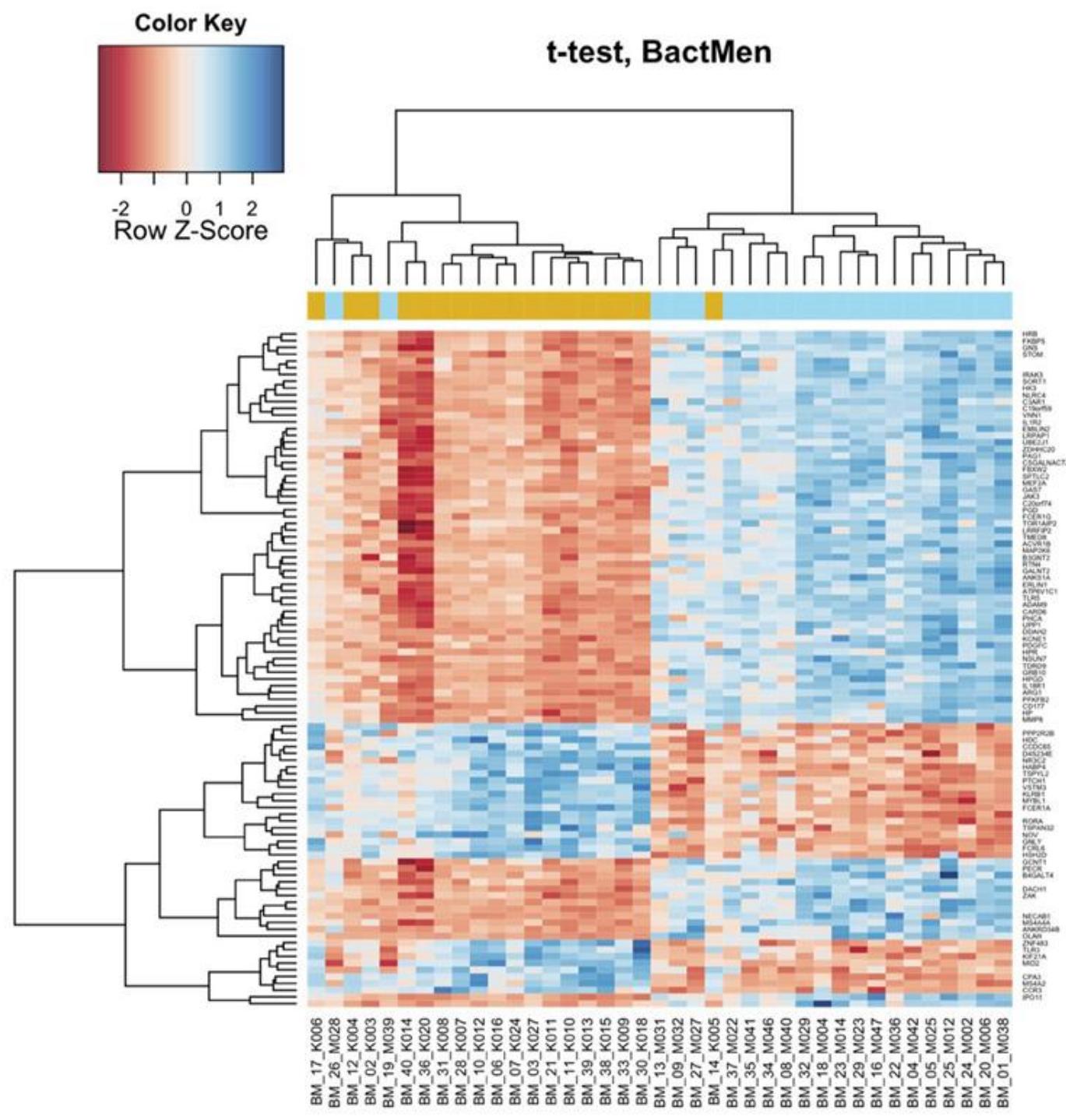
d3.interpolateMagma(t) <>



d3.interpolateCividis(t) <>







SPENDING PER STUDENT, BY SCHOOL DISTRICT

Adjusted for regional differences, for primary and unified school districts

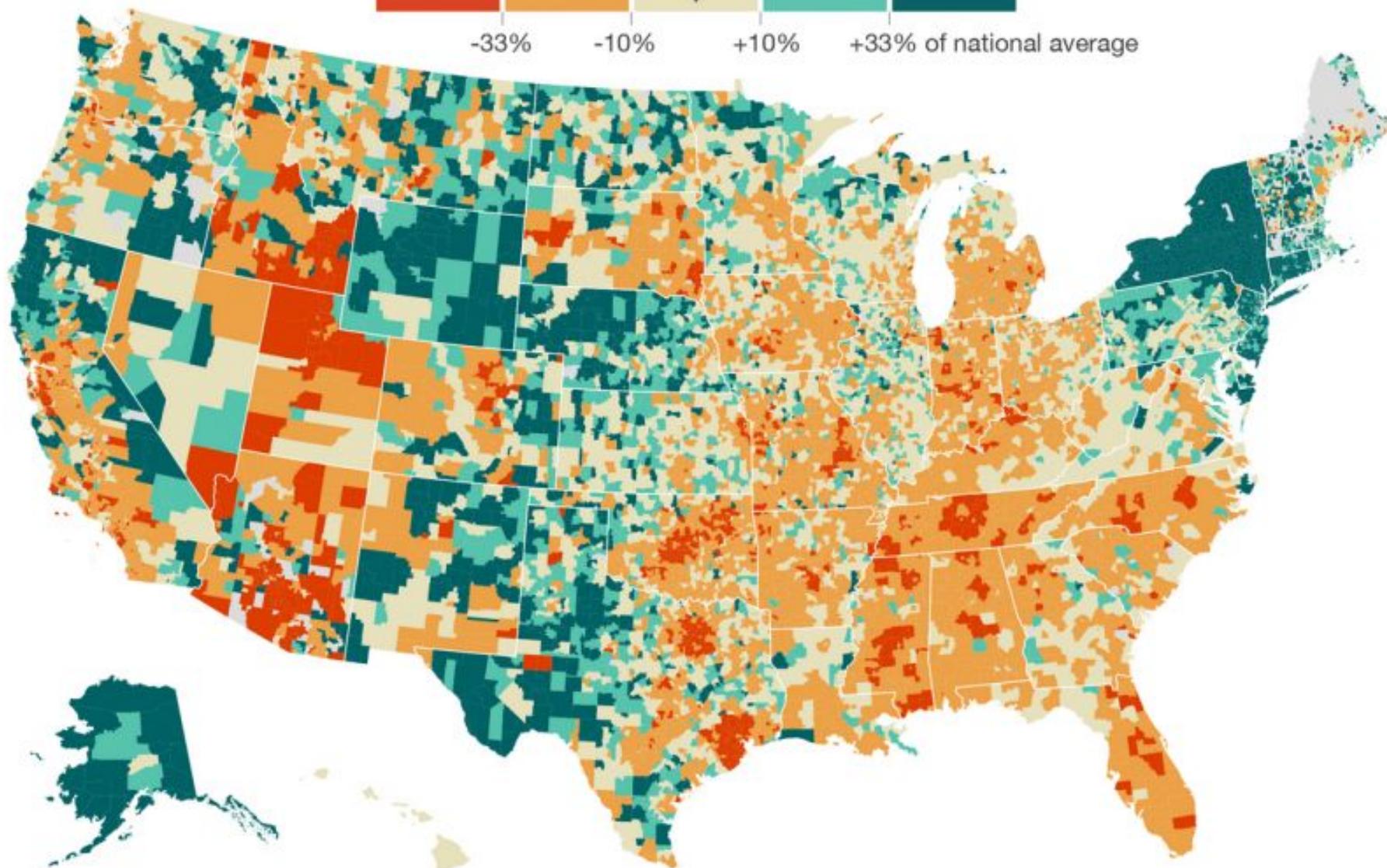
National average: \$11,841

-33%

-10%

+10%

+33% of national average



health expenditure % of GDP	-0.178	0.236	0.304		0.408	0.282	0.381	-0.310	-0.429	0.243	0.235	0.273	0.350	0.320	0.210	0.114
health expenditure per person	-0.378	0.737	0.753	0.408		0.179	0.880	-0.49	-0.485	0.509	0.796	0.778	0.750	0.714	0.620	0.268
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								-0.71	-0.647	-0.684	-0.738	-0.627	-0.508	-0.125		
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Session 2e

Categorical Scales

- education expenditure % of GDP
- education expenditure per person
- political stability & absence of violence
- regulatory quality
- rule of law
- control of corruption
- overall economic freedom score
- women MPs (% of all MPs)

- Negatively correlated with -

- GINI Index
- political rights score
- civil liberties score

Pearson Correlation coefficient 5:

-1.0	-1.0	0.0	0.0
-0.9	-0.9	0.1	0.1
-0.8	-0.8	0.2	0.2
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-0.4	-0.4	0.6	0.6
-0.3	-0.3	0.7	0.7
-0.2	-0.2	0.8	0.8
-0.1	-0.1	0.9	0.9
0.0	0.0	1.0	1.0

* Pearson coefficients measure the strength and direction of the linear relationship between the two variables

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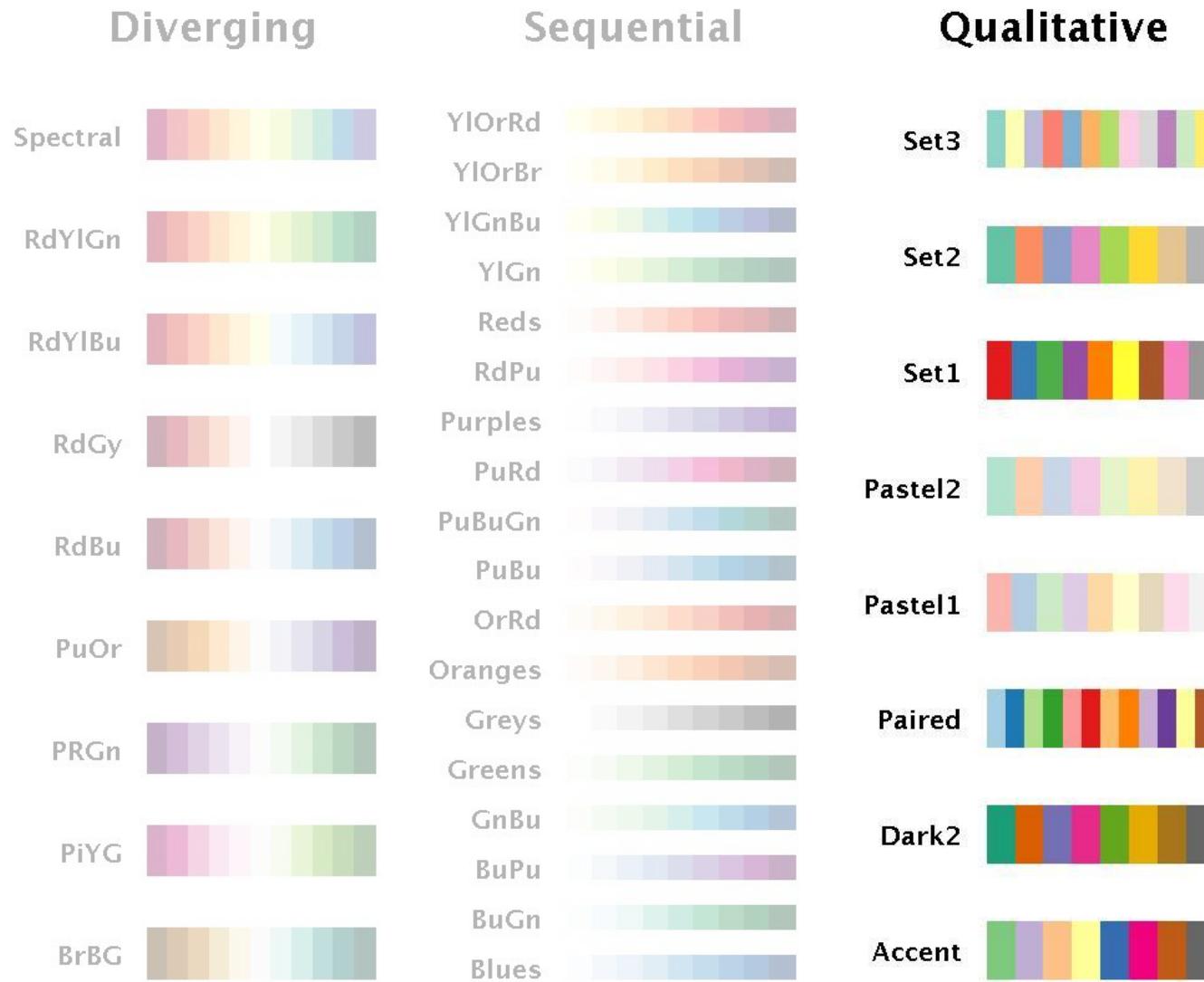
May 2022

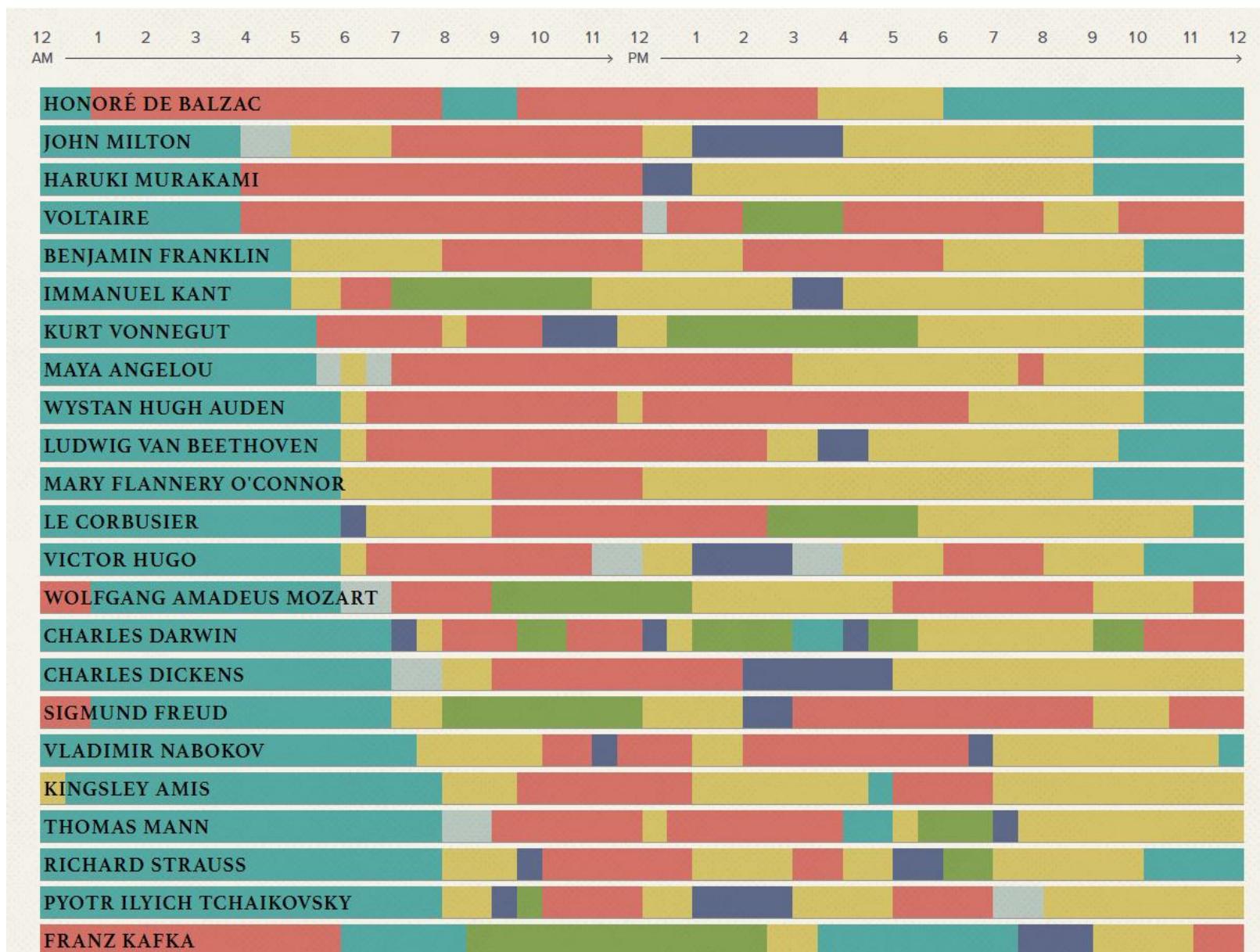
<http://benjbach.me>

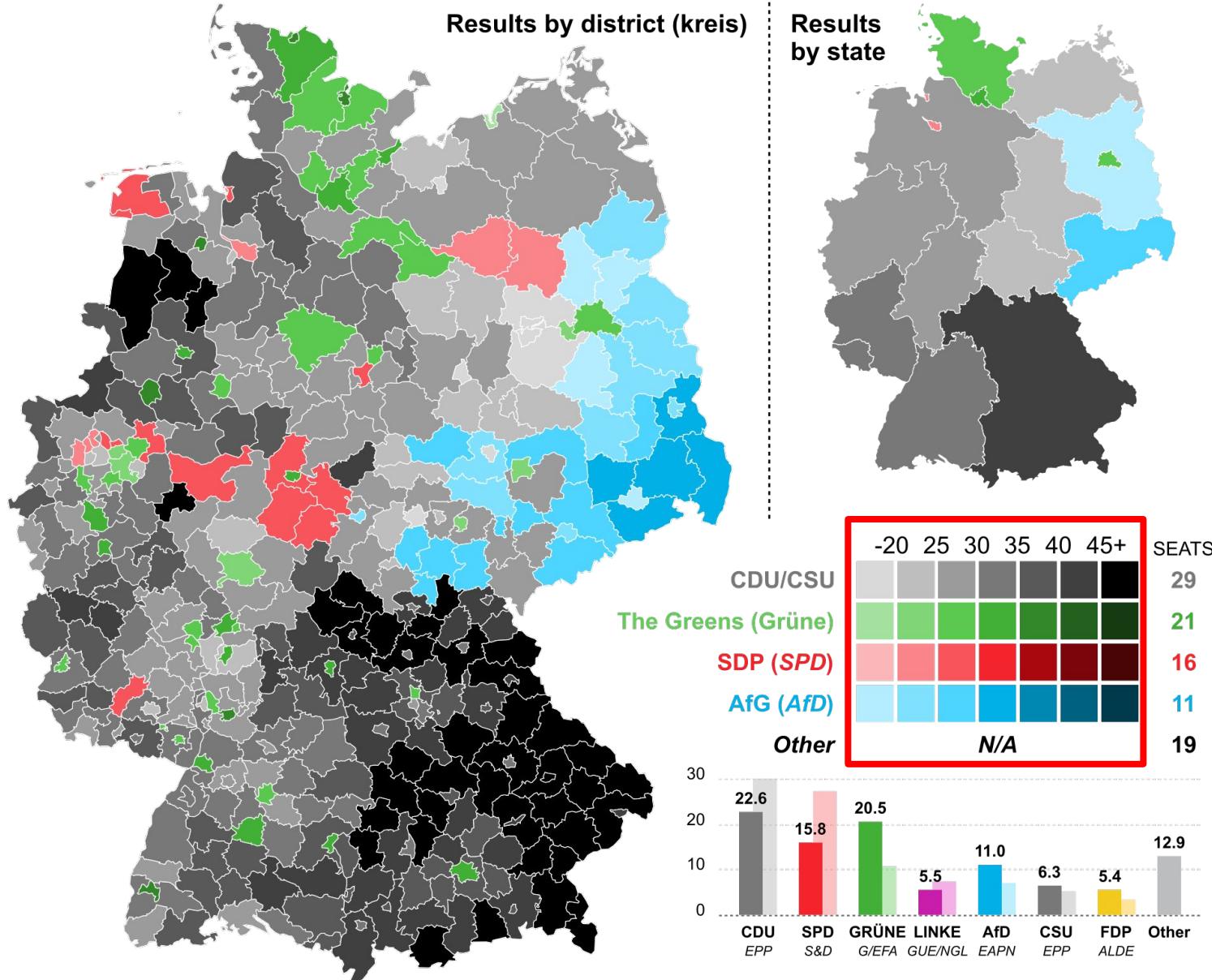
<https://datavis-online.github.io>

-- Not for external use --

More examples of color scales (ColorBrewer)







I Want Hue

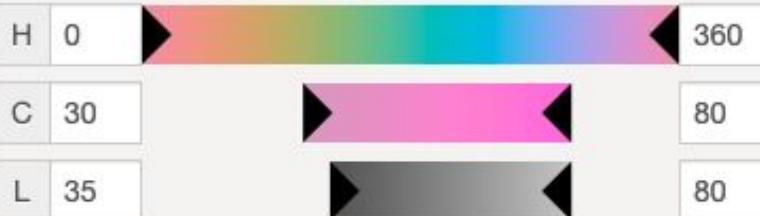


i want hue

Colors for data science
optimally distinct colors

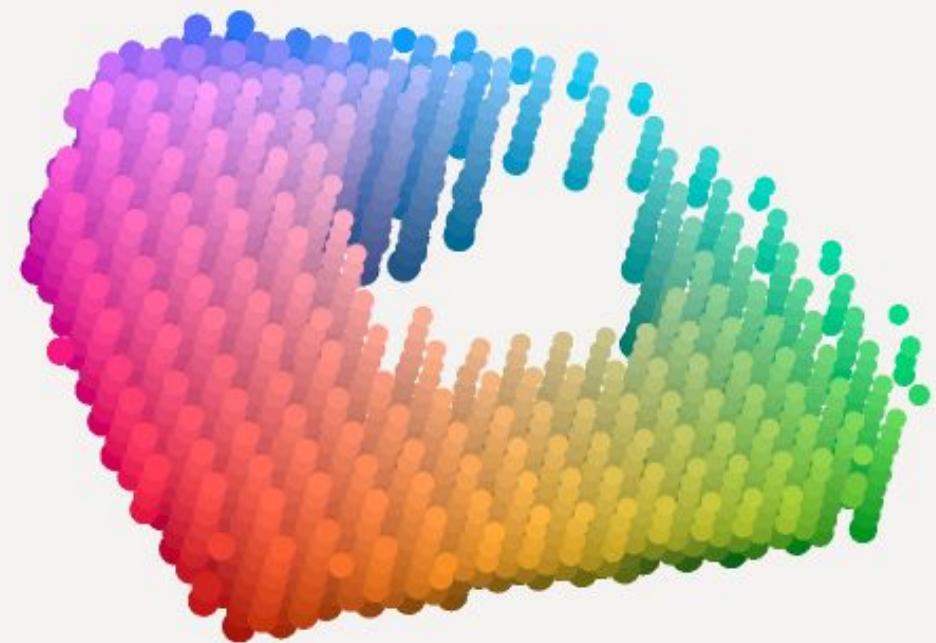
Color space

Default preset



Improve for the colorblind (slow)

Dark background

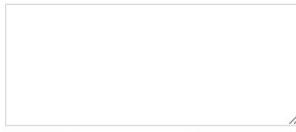


VIZ PALETTE

By: Elijah Meeks
& Susie Lu

PICK

Use Chroma.js



Add

Replace

Use Colorgorical

ColorBrewer is developed by Cynthia Brewer

Use
ColorBrewer

Go to this block to find colors, then paste them above.

EDIT

7 Colors

Add

hex rgb

hsl

- ≡ 1 ● #ffd700 ↗ ×
- ≡ 2 ● #ffb14e ↗ ×
- ≡ 3 ● #fa8775 ↗ ×
- ≡ 4 ● #ea5f94 ↗ ×
- ≡ 5 ● #cd34b5 ↗ ×
- ≡ 6 ● #9d02d7 ↗ ×
- ≡ 7 ● #0000ff ↗ ×

GET

- String quotes
 Object with metadata

```
[ "#ffd700",
  "#ffb14e",
  "#fa8775",
  "#ea5f94",
  "#cd34b5",
  "#9d02d7",
  "#0000ff" ]
```

hex rgb

COLORS IN ACTION

Charts made with [Semiotic](#)

Color Population:

No Color Deficiency - 96%

Deuteranomaly - 2.7%

Protanomaly - 0.66%

Protanopia - 0.59%

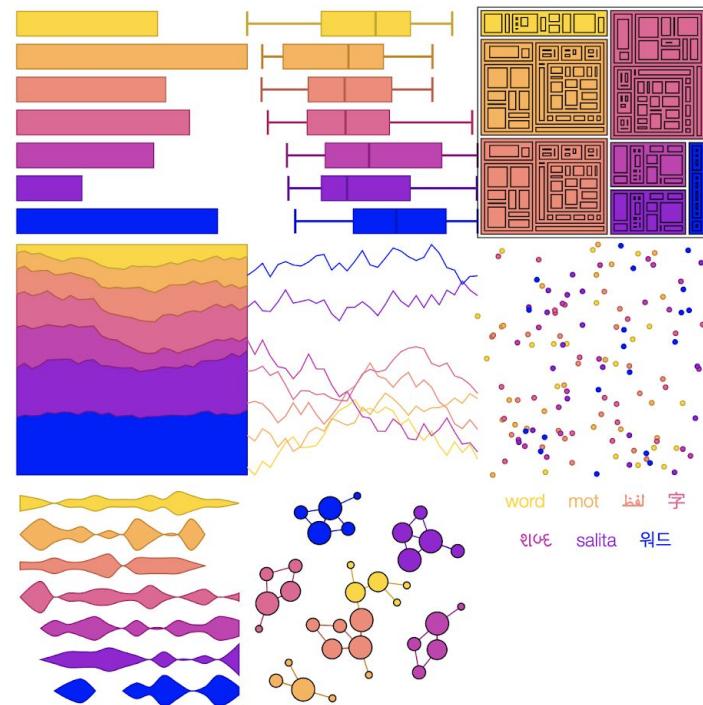
Deuteranopia - 0.56%

Greyscale

Sample font

Randomize Data

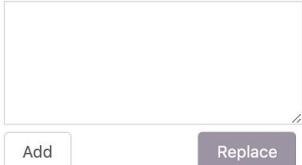
Stroke: Dark None



VIZ PALETTE

By: Elijah Meeks
& Susie Lu

PICK



Add

Replace

Use Chroma.js

Use Colorgorical

Use
ColorBrewer

ColorBrewer is developed by
Cynthia Brewer

Go to [this block](#) to find colors, then
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GET

hex rgb

hsl

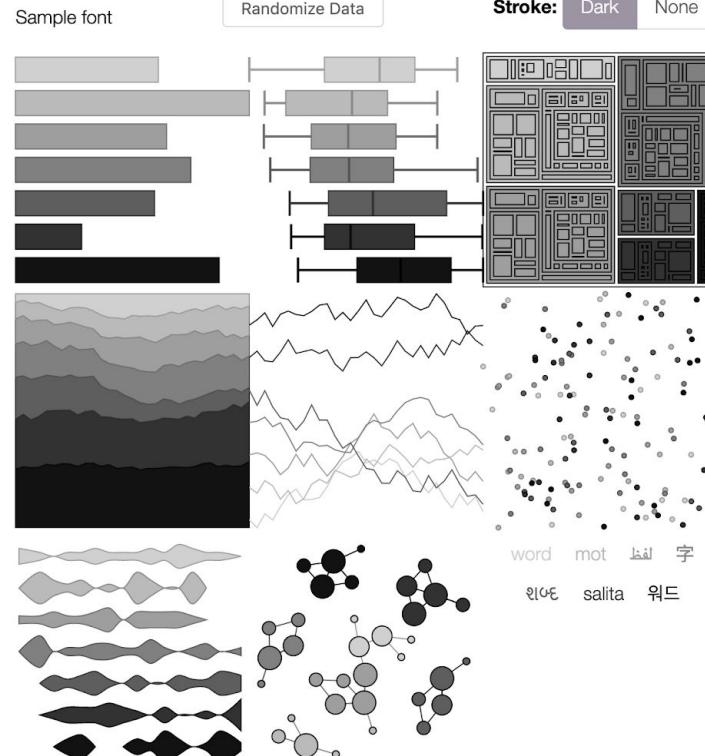
String quotes
 Object with metadata

```
[ "#ffd700",
  "#ffb14e",
  "#fa8775",
  "#ea5f94",
  "#cd34b5",
  "#9d02d7",
  "#0000ff"]
```

COLORS IN ACTION

Font color: █ #uuuuuu ↗

Charts made with [Semiotic](#)



Font color: #UUUUUU ↗

Charts made with [Semiotic](#)

COLORS IN ACTION

VIZ PALETTE

By: Elijah Meeks
& Susie Lu

PICK

Use Chroma.js

Use Colorgorical

ColorBrewer is developed by Cynthia Brewer

Use ColorBrewer

Go to [this block](#) to find colors, then paste them above.

EDIT

≡ 1 ffd700 ↗

✗

≡ 2 ffb14e ↗

✗

≡ 3 fa8775 ↗

✗

≡ 4 ea5f94 ↗

✗

≡ 5 cd34b5 ↗

✗

≡ 6 9d02d7 ↗

✗

≡ 7 #0000ff ↗

✗

GET

String quotes

Object with metadata

```
[ "#ffd700",
  "#ffb14e",
  "#fa8775",
  "#ea5f94",
  "#cd34b5",
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  "#0000ff"]
```

hex

rgb

hsl

Color Population:

No Color Deficiency - 96%

Deuteranomaly - 2.7%

Protanomaly - 0.66%

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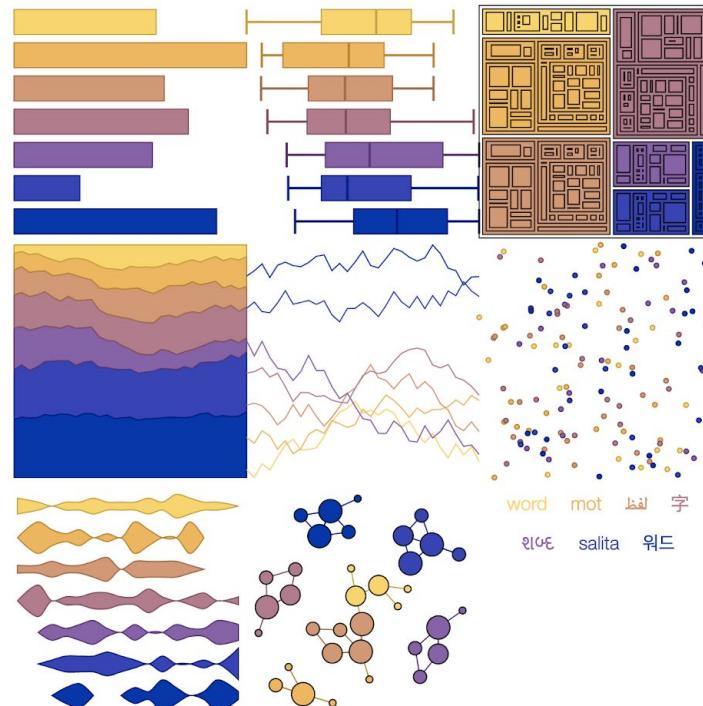
Deuteranopia - 0.56%

Greyscale

Sample font

Randomize Data

Stroke: Dark None



Basic color terms recur across languages

Fruits

- Apple
- Banana
- Blueberry
- Cherry
- Grape

Brands

- Apple
- AT&T
- Home Depot
- Kodak
- Starbucks

Lin et al. (2013) Selecting
Semantically-Resonant Colors
for Data Visualization



Session 2e

Rainbow Colormaps



- education expenditure % of GDP
 - education expenditure per person
 - political stability & absence of violence
 - regulatory quality
 - rule of law
 - control of corruption
 - overall economic freedom score
 - women MPs (% of all MPs)
- Negatively correlated with

- GINI Index
- political rights score
- civil liberties score

relation coefficient 5

0.0	0.0	* Pearson coefficients measure the strength and direction of the linear relationship between the two variables
0.1	0.1	
0.2	0.2	
0.3	0.3	
0.4	0.4	
0.5	0.5	-1 → perfect negative correlation
0.6	0.6	0 → no correlation
0.7	0.7	
0.8	0.8	
0.9	0.9	1 → perfect positive correlation
1.0	1.0	

* a variable correlated with itself will always have a correlation coefficient of 1.

★ Data from 2017 and earlier ★



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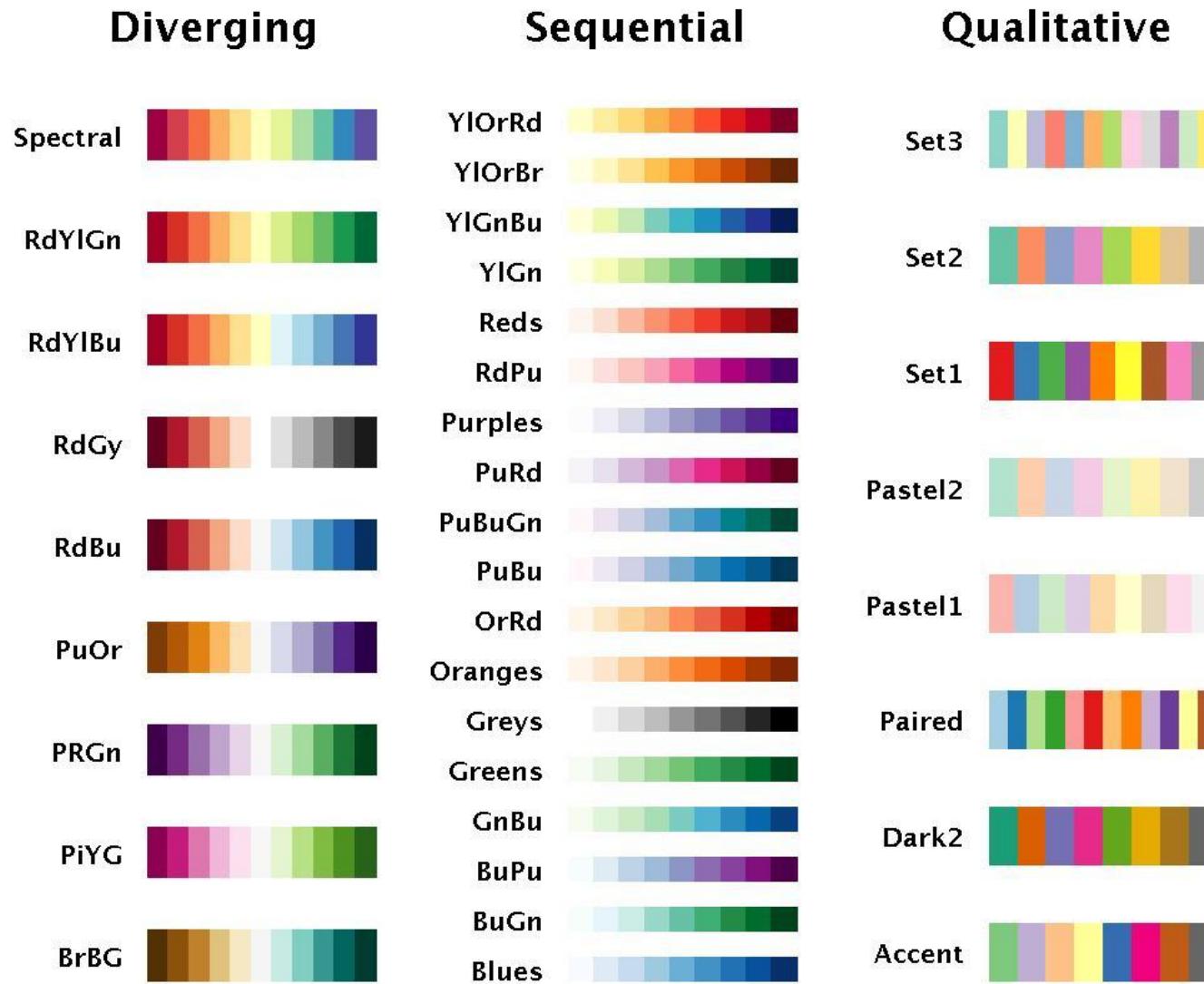
May 2022

<http://benjbach.me>

<https://datavis-online.github.io>

-- Not for external use --

More examples of color scales (ColorBrewer)

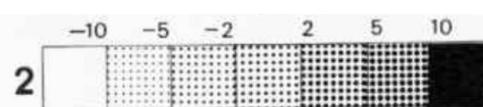


Rainbow Scale Considerations

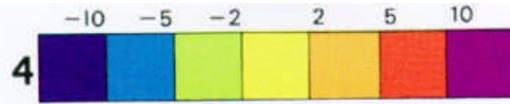
Map 1



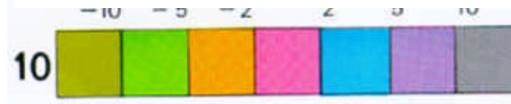
1



2

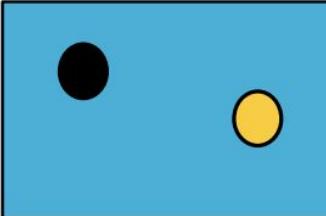
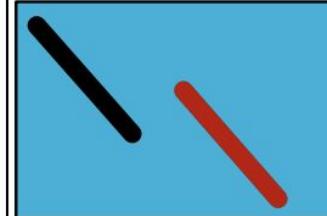
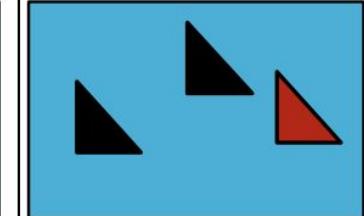
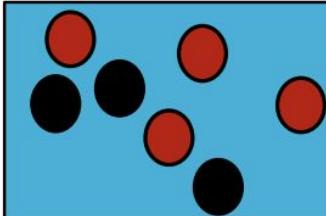
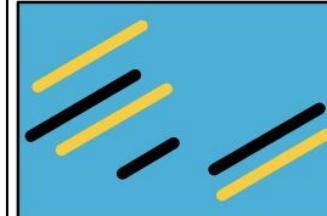
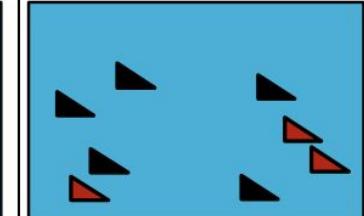
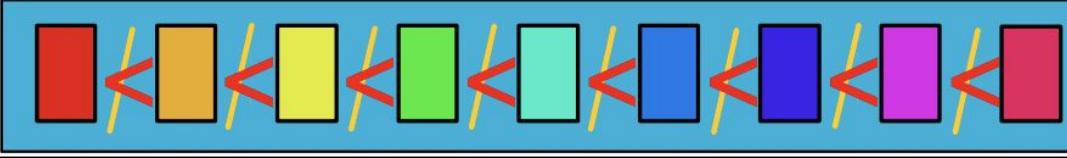


4



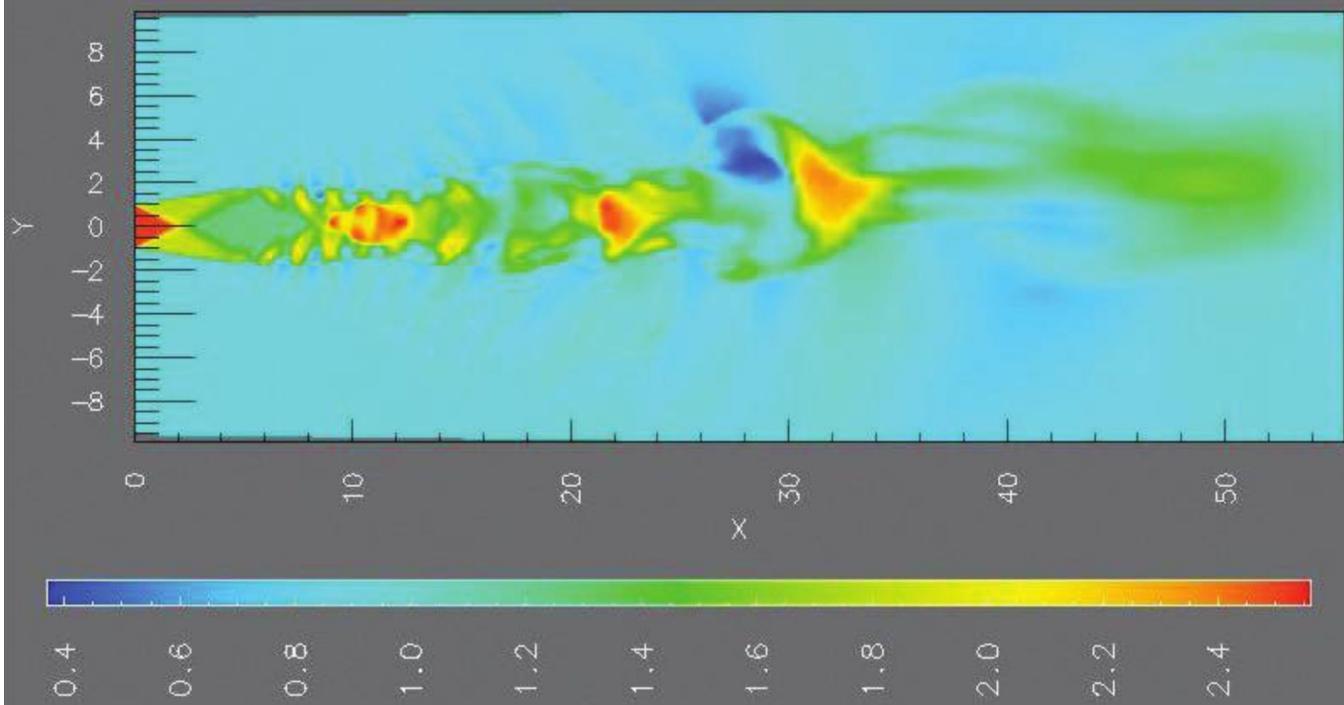
10

Visual Variable: Colour

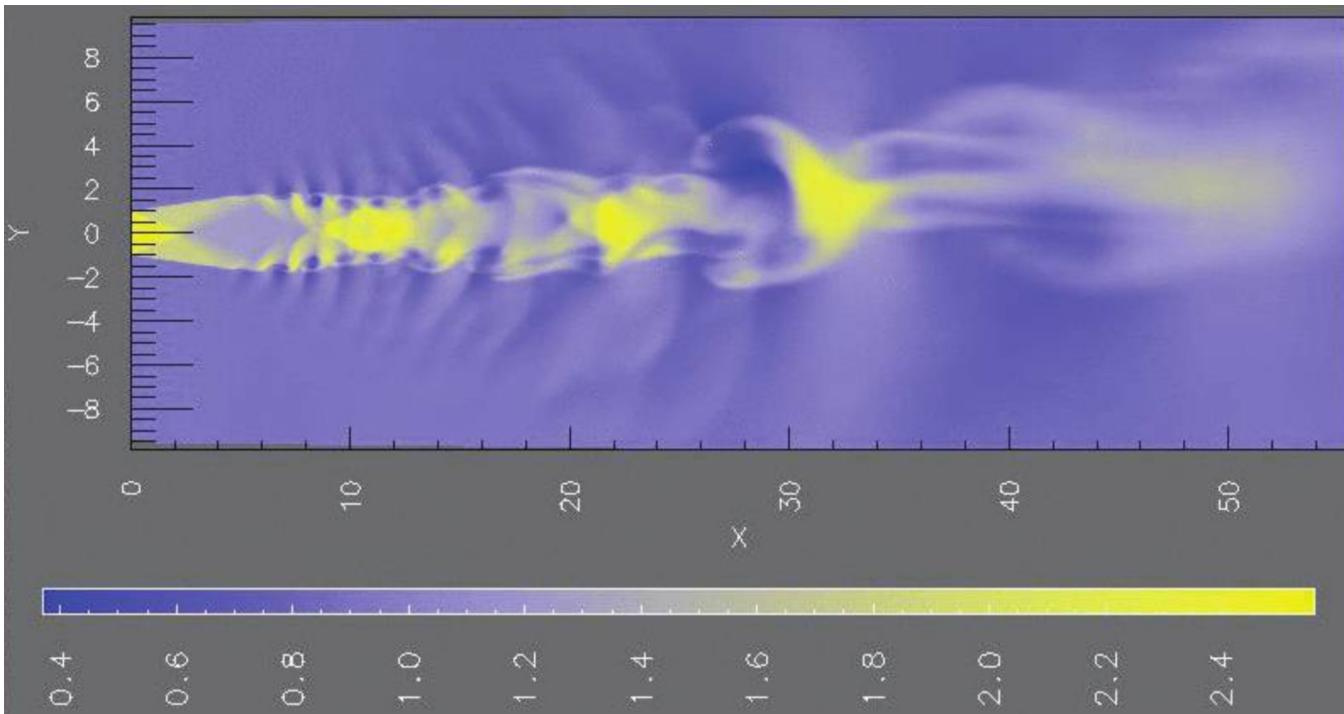
	selective			
	associative			
	quantitative			
	order			
	length		<ul style="list-style-type: none"> • theoretically infinite but practically limited • association and selection ~ < 7 and distinction ~ 10 	

Color Maps

Rainbow:

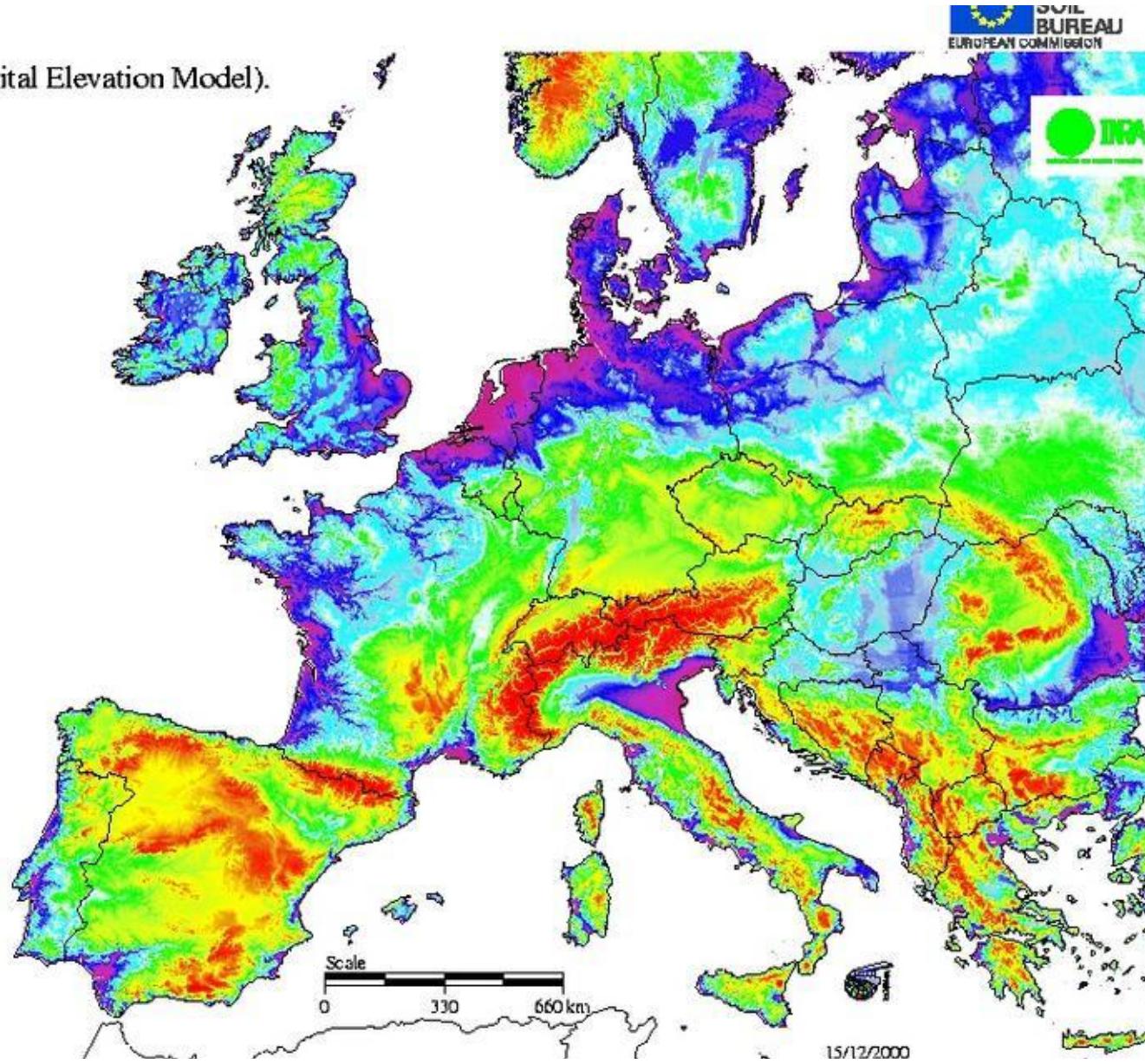


Diverging:



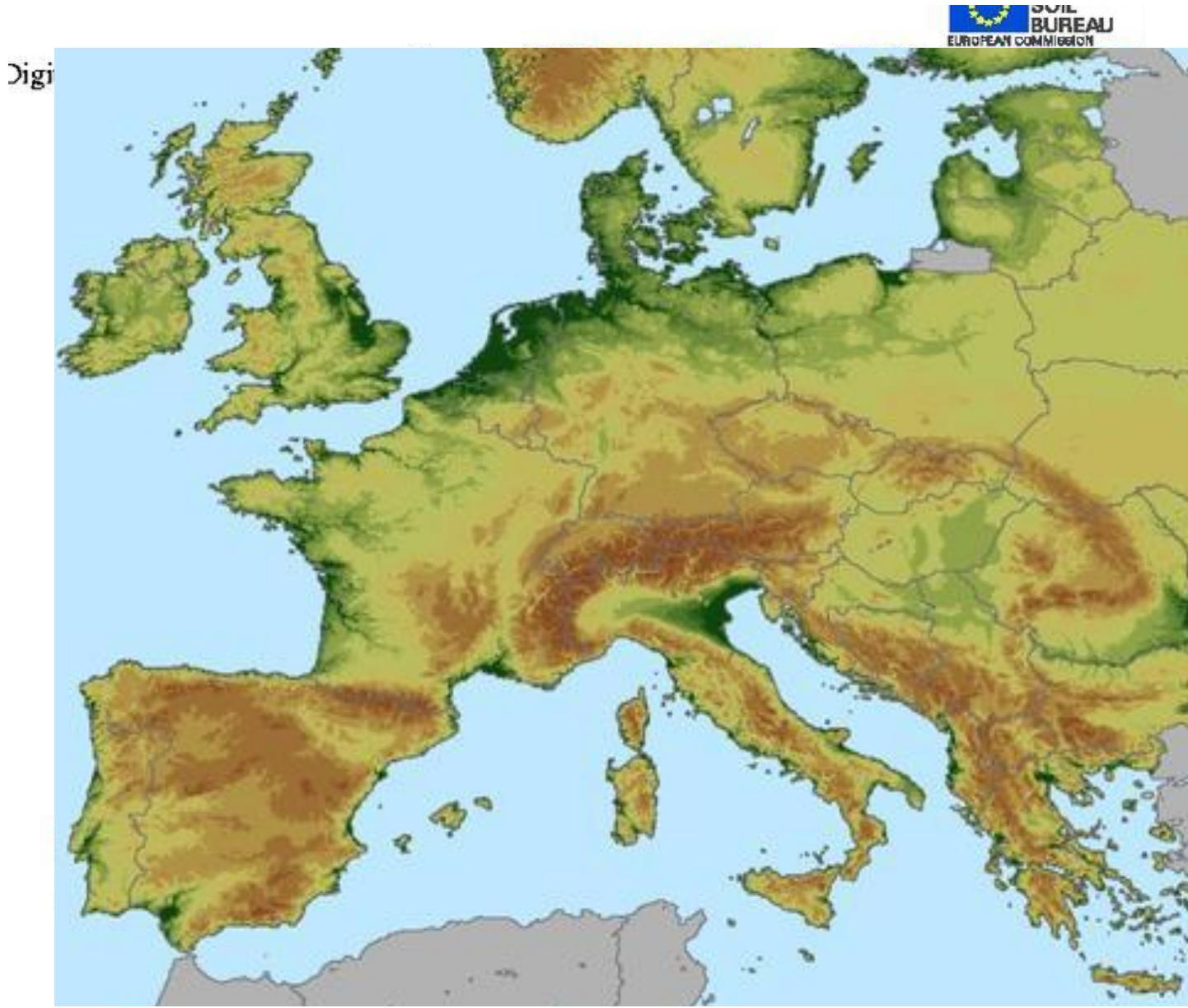
Rainbow Colormap

Digital Elevation Model).



15/12/2000

Rainbow Colormap



Color (mis)use

Country Level Sales Rank Top 5 Drugs

Rainbow distribution in color indicates sales rank in given country from #1 (red) to #10 or higher (dark purple)

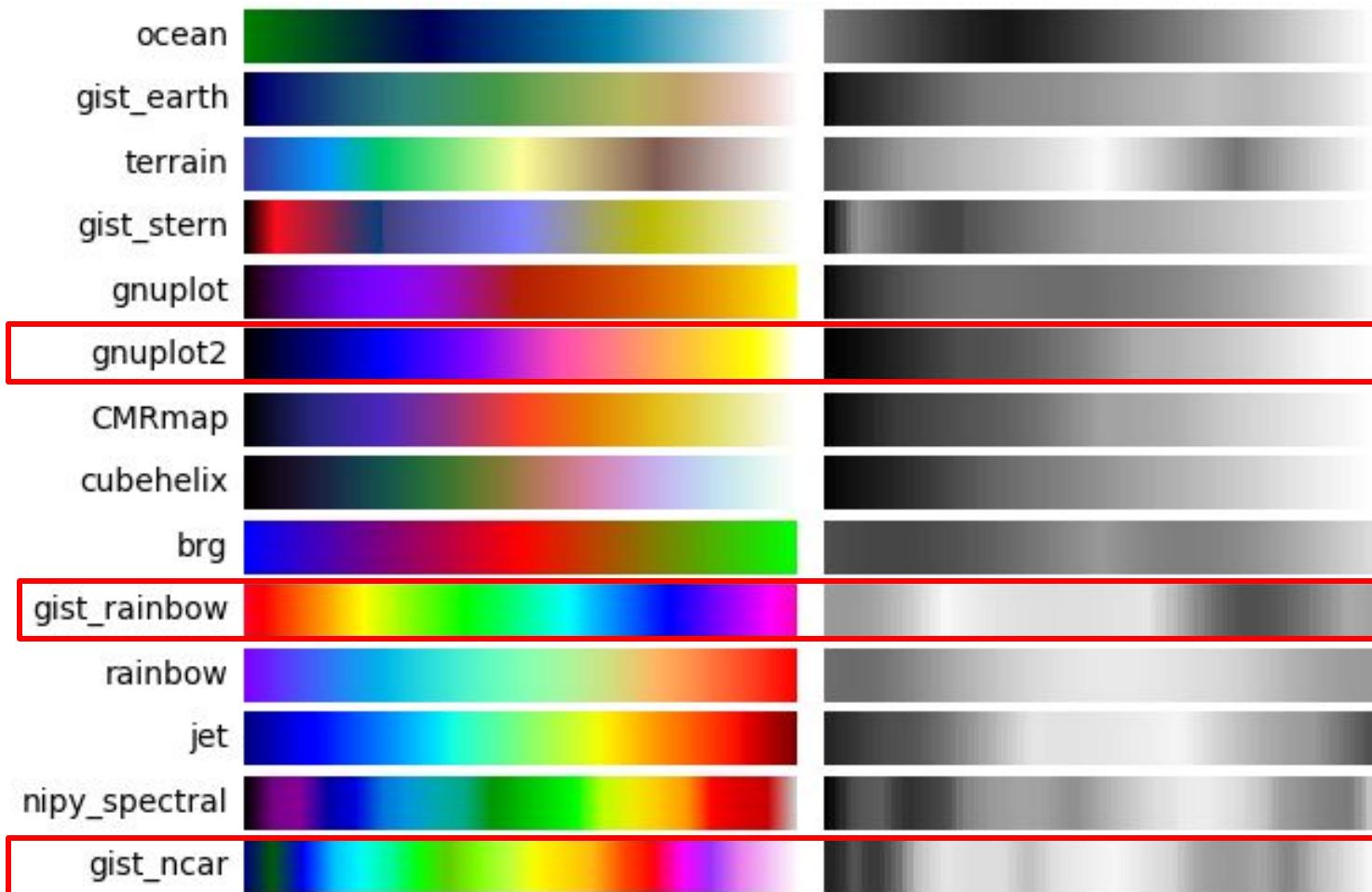
Country	A	B	C	D	E
AUS	1	2	3	6	7
BRA	1	3	4	5	6
CAN	2	3	6	12	8
CHI	1	2	8	4	7
FRA	3	2	4	8	10
GER	3	1	6	5	4
IND	4	1	8	10	5
ITA	2	4	10	9	8
MEX	1	5	4	6	3
RUS	4	3	7	9	12
SPA	2	3	4	5	11
TUR	7	2	3	4	8
UK	1	2	3	6	7
US	1	2	4	3	5

Top 5 drugs: country-level sales rank

RANK	1	2	3	4	5+
COUNTRY DRUG	A	B	C	D	E
Australia	1	2	3	6	7
Brazil	1	3	4	5	6
Canada	2	3	6	12	8
China	1	2	8	4	7
France	3	2	4	8	10
Germany	3	1	6	5	4
India	4	1	8	10	5
Italy	2	4	10	9	8
Mexico	1	5	4	6	8
Russia	4	3	7	9	12
Spain	2	3	4	5	11
Turkey	7	2	3	4	8
United Kingdom	1	2	3	6	7
United States	1	2	4	3	5

FIGURE 4.15 Use color sparingly

Lightness perception of rainbow color maps



Rainbow colormap

Pros:

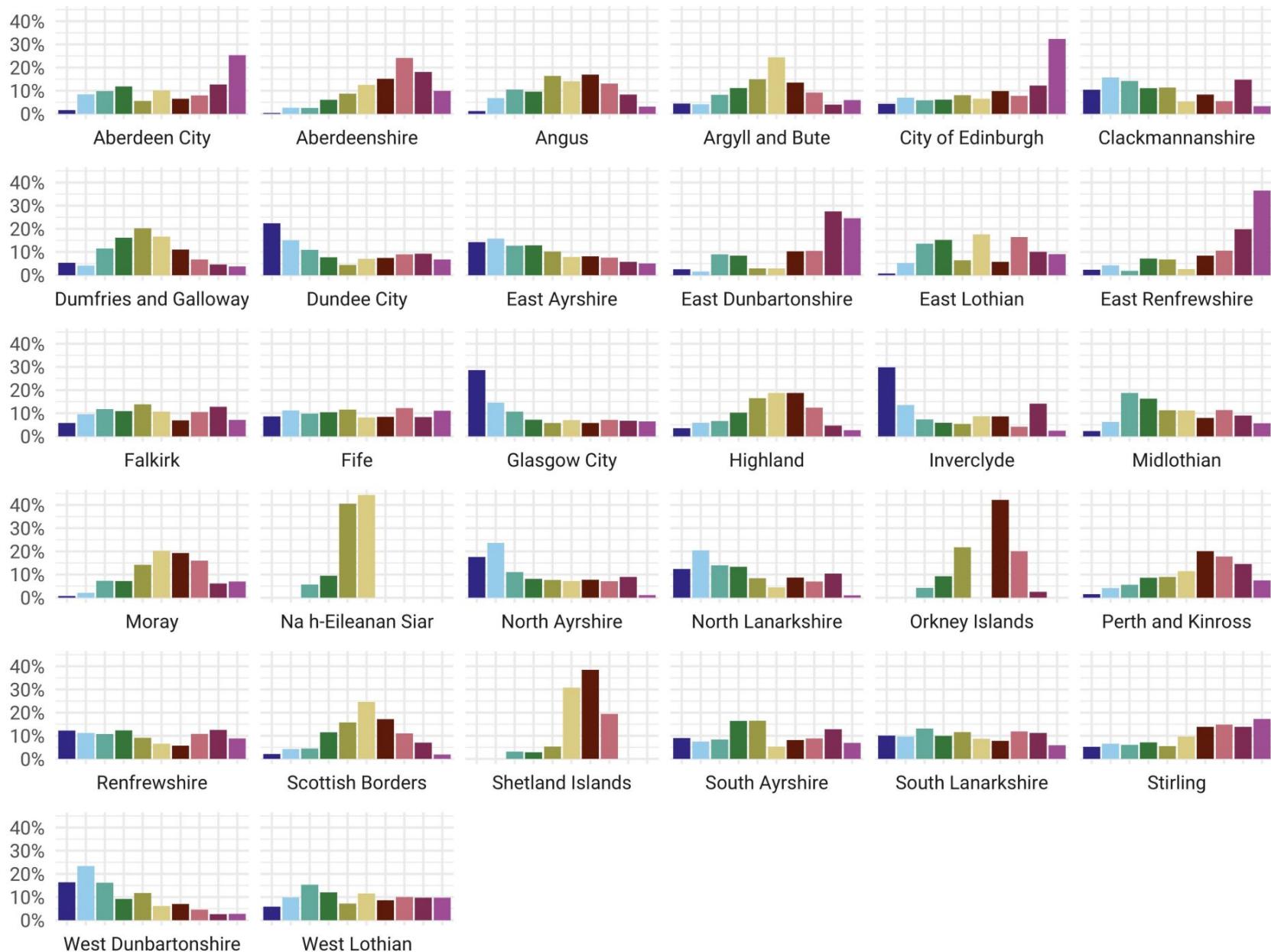
- Many different values
- Compare similar values

Cons:

- Colors hardly orderable
- Introduces sharp jumps in values
- Hides overall patterns
- Overemphasizes certain values
- Is not black/white nor colorblind save!

**Linear
Rainbow
map**





SIMD decile ■ 1-most deprived ■ 2 ■ 3 ■ 4 ■ 5 ■ 6 ■ 7 ■ 8 ■ 9 ■ 10-most affluent

health expenditure % of GDP	-0.178	0.236	0.304		0.408	0.282	0.381	-0.310	-0.429	0.243	0.235	0.273	0.350	0.320	0.210	0.114
health expenditure per person	-0.378	0.737	0.753	0.408		0.179	0.880	-0.49	-0.485	0.509	0.796	0.778	0.750	0.714	0.620	0.268
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overall economic freedom score										0.810	0.705	0.269				
women MPs (% of all MPs)										0.781	0.813	0.230				

- education expenditure % of GDP
- education expenditure per person
- political stability & absence of violence
- regulatory quality
- rule of law
- control of corruption
- overall economic freedom score
- women MPs (% of all MPs)

Negatively correlated with

- GINI Index
- political rights score
- civil liberties score

(Pearson Correlation coefficient 5)

-1.0	-1.0	0.0	0.0
-0.9	-0.9	0.1	0.1
-0.8	-0.8	0.2	0.2
-0.7	-0.7	0.3	0.3
-0.6	-0.6	0.4	0.4
-0.5	-0.5	0.5	0.5
-0.4	-0.4	0.6	0.6
-0.3	-0.3	0.7	0.7
-0.2	-0.2	0.8	0.8
-0.1	-0.1	0.9	0.9
0.0	0.0	1.0	1.0

* Pearson coefficients measure the strength and direction of the linear relationship between the two variables

-1 → perfect negative correlation

0 → no correlation

1 → perfect positive correlation

* a variable correlated with itself will always have a correlation coefficient of 1.

★ Data from 2017 and earlier ★



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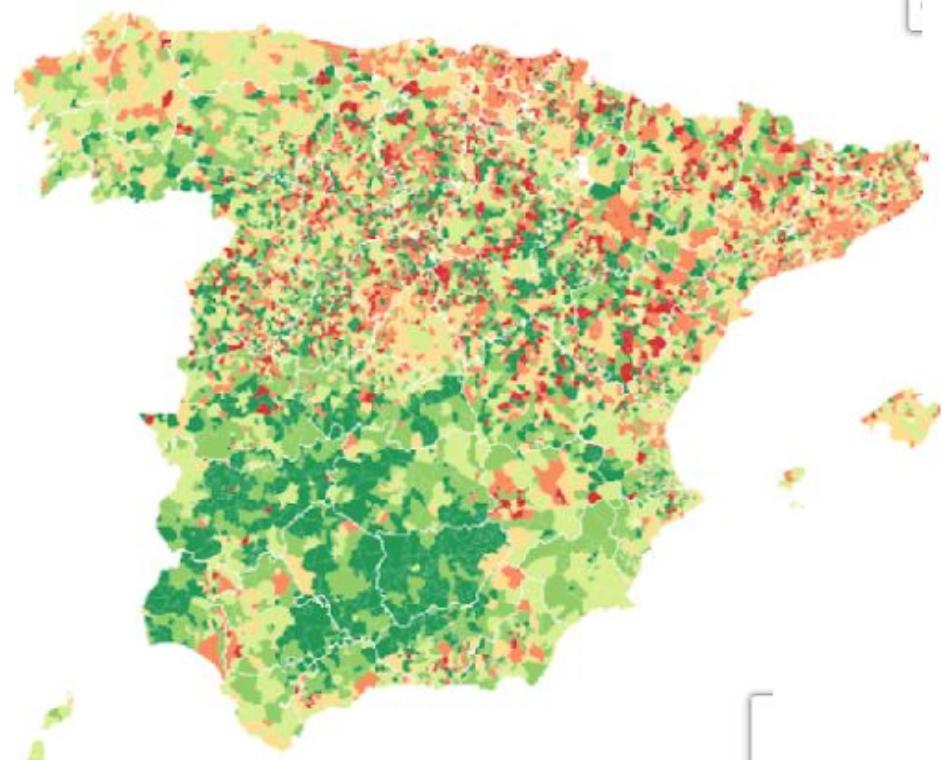
Benjamin Bach

May 2022

<http://benjbach.me>

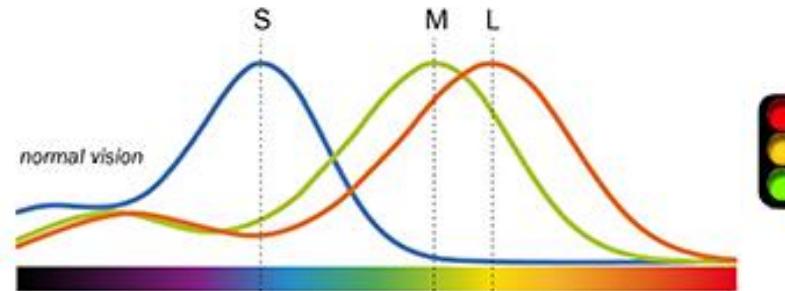
<https://datavis-online.github.io>

-- Not for external use --

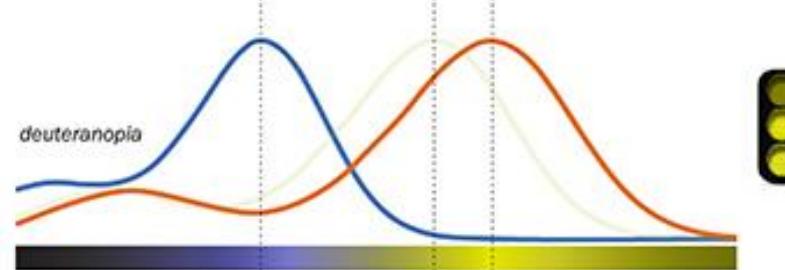


eye response to color in color blindness
RELATIVE ABSORPTION OF COLOR PHOTORECEPTORS
AND APPEARANCE OF SPECTRUM AND OBJECTS

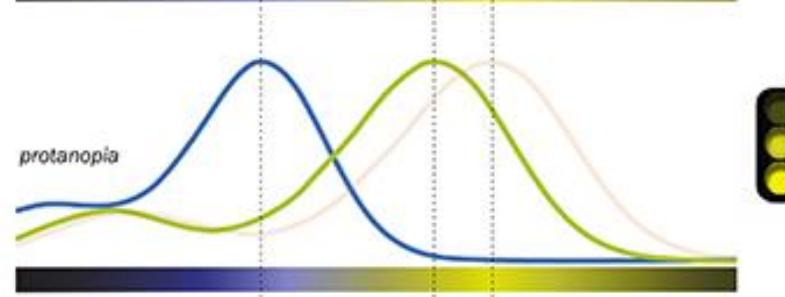
Normal vision



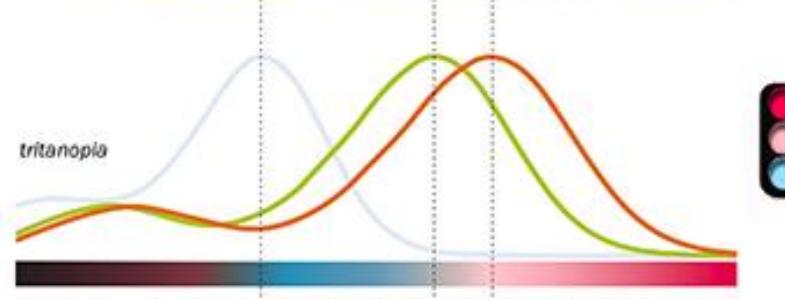
Deutanopia



Protanopia



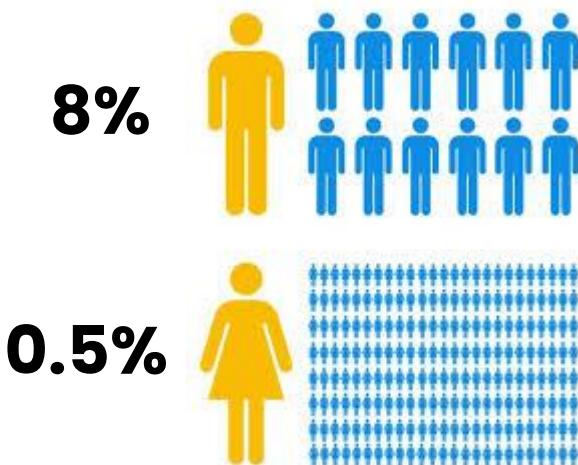
Tritanopia



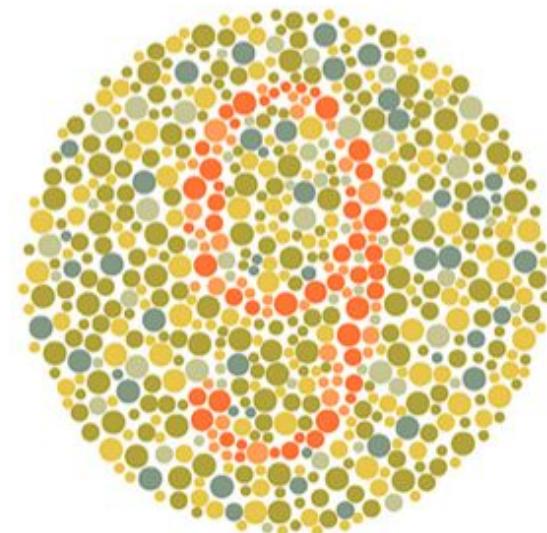
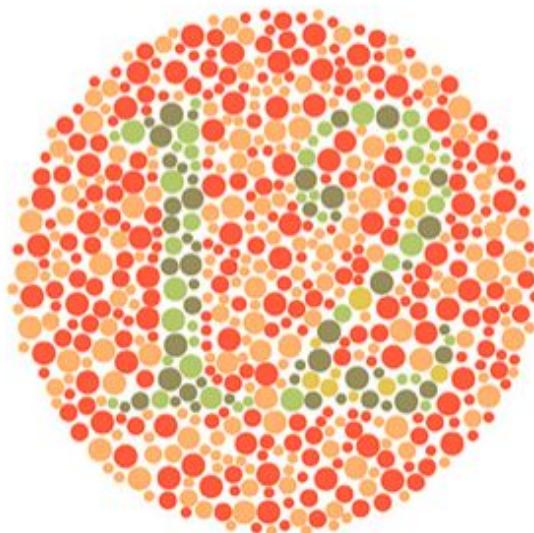
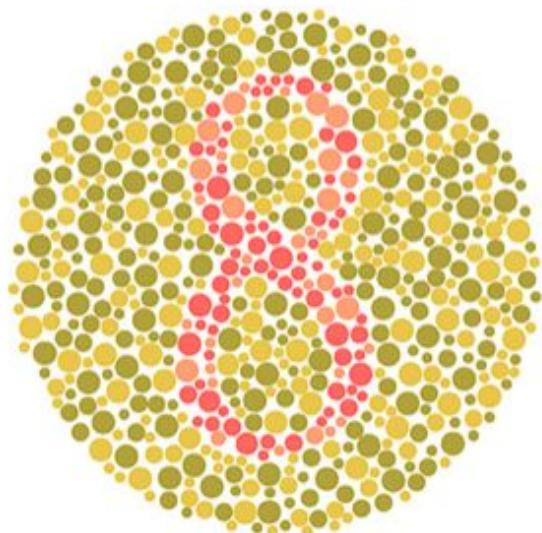
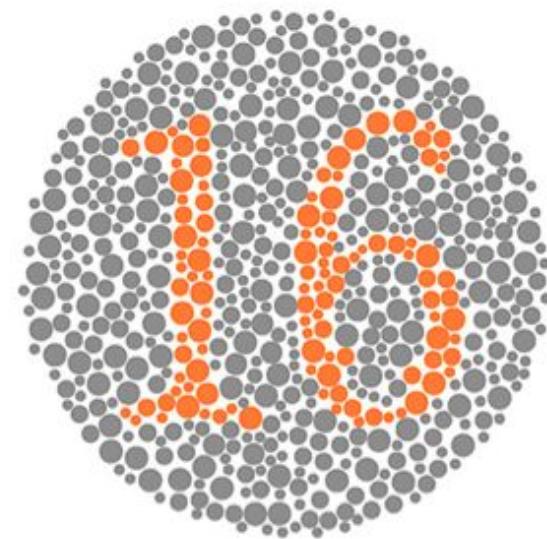
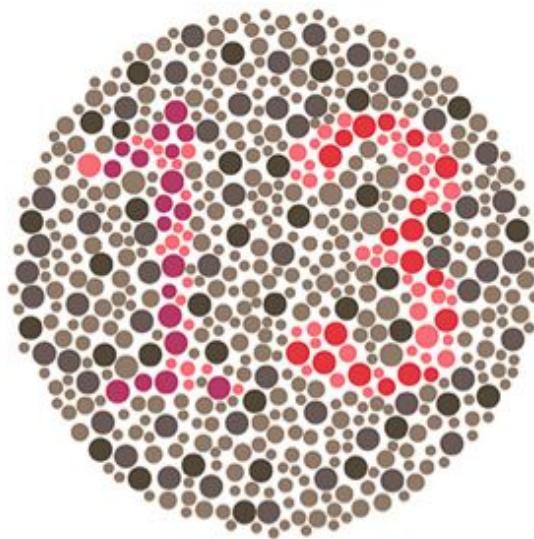
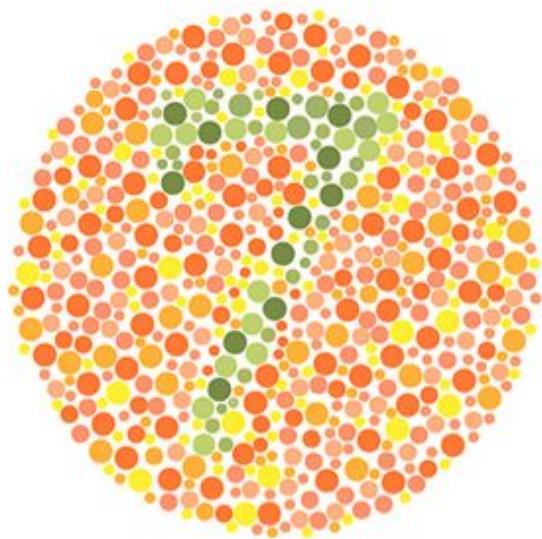
300 400 500 600 700 nm

	Protanopia	Deuteranopia	Tritanopia
Men	91.4%	2.45%	0.011%
Women	99.6%	0.04%	0.04%
Overall	95.5%	1.25%	0.025%

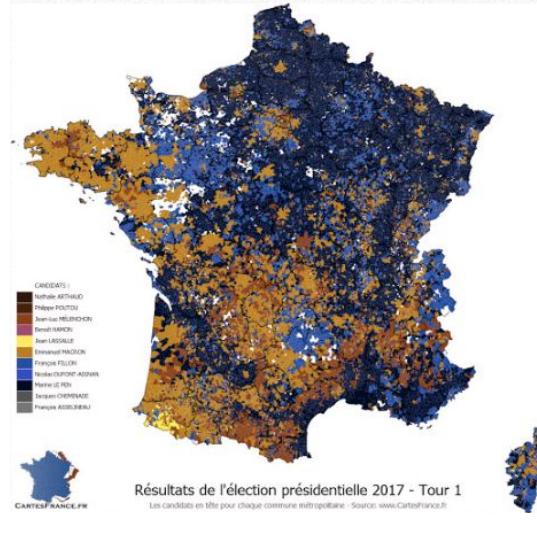
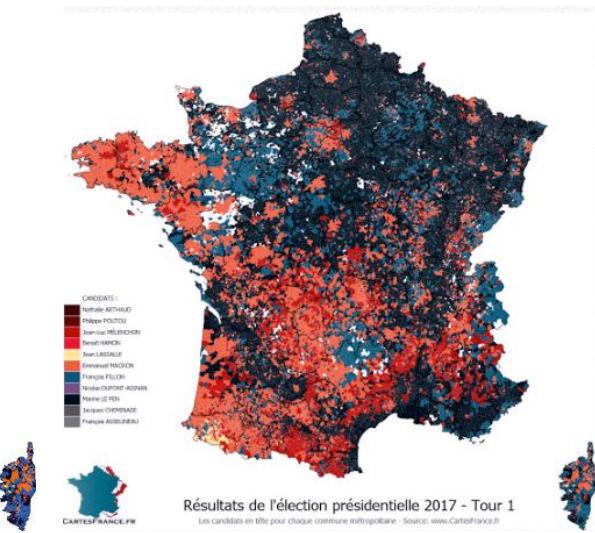
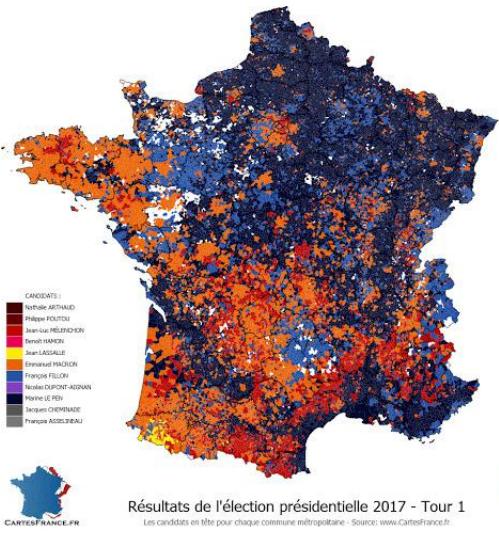
Red
Orange
Yellow
Green
Blue
Magenta



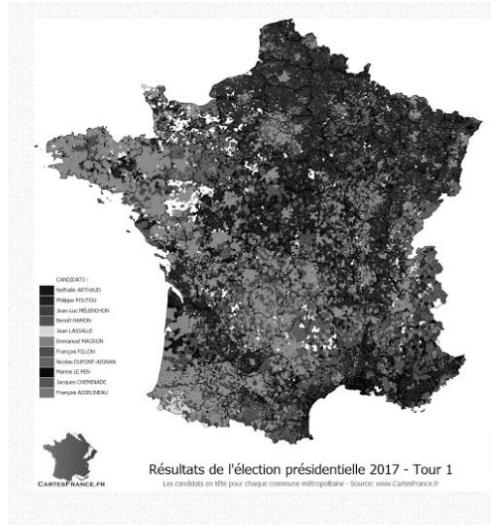
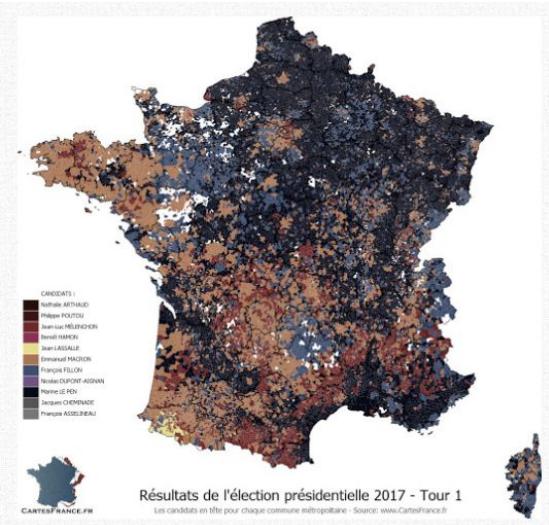
"If a submitted manuscript happens to go to **three male reviewers** of Northern European descent, the chance that at least one will be color blind is **22 percent**."



www.color-blindness.com



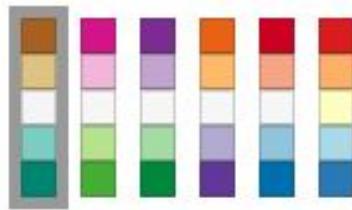
Normal



Types of color blindness

Colorblind safe palettes

Colorbrewer.org:



Diverging



Sequential

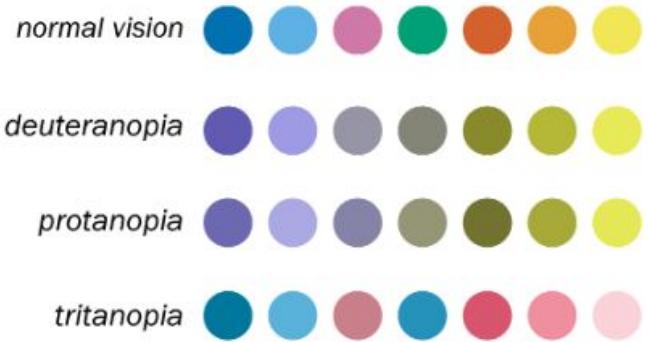


Categorical

Color	Color name	RGB (1–255)	CMYK (%)	P	D
Black	Black	0, 0, 0	0, 0, 0, 100	█	█
Orange	Orange	230, 159, 0	0, 50, 100, 0	█	█
Sky blue	Sky blue	86, 180, 233	80, 0, 0, 0	█	█
Bluish green	Bluish green	0, 158, 115	97, 0, 75, 0	█	█
Yellow	Yellow	240, 228, 66	10, 5, 90, 0	█	█
Blue	Blue	0, 114, 178	100, 50, 0, 0	█	█
Vermillion	Vermillion	213, 94, 0	0, 80, 100, 0	█	█
Reddish purple	Reddish purple	204, 121, 167	10, 70, 0, 0	█	█

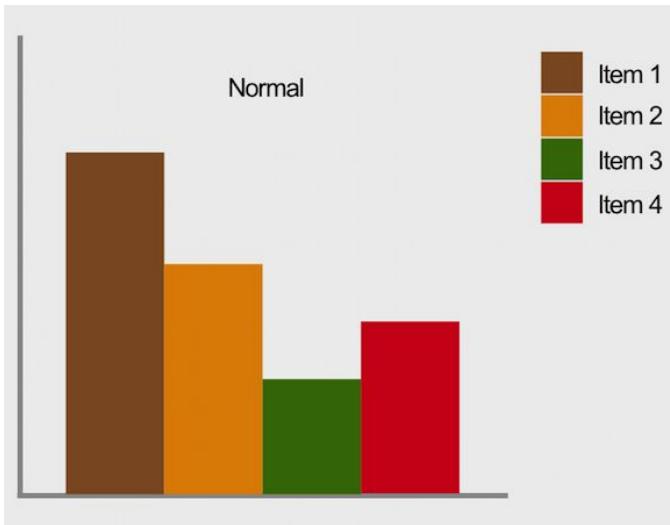
Wong, B. (2011) Points of view: Color blindness. Nature Methods 8:441.

SORTED BY SIMILARITY IN DEUTERANOPIA



<http://mkweb.bcgsc.ca/colorblind>

Redundant encoding



health expenditure % of GDP	-0.178	0.236	0.304		0.408	0.282	0.381	-0.310	-0.429	0.243	0.235	0.273	0.350	0.320	0.210	0.114
health expenditure per person	-0.378	0.737	0.753	0.408		0.179	0.880	-0.49	-0.485	0.509	0.796	0.778	0.750	0.714	0.620	0.268
education expenditure % of GDP	-0.092	0.254	0.418	0.282	0.179		0.379	-0.486	-0.439	0.231	0.34	0.314	0.337	0.396	0.124	0.335
education expenditure per person	-0.417	0.662	0.322	0.381	0.880	0.379		-0.431	-0.497	0.514	0.786	0.774	0.745	0.716	0.623	0.369
political rights score								0.947	-0.694	-0.545	-0.637	-0.677	-0.581	-0.479	-0.129	
								-0.71	-0.647	-0.684	-0.738	-0.627	-0.508	-0.125		

Session 2e

Further Applications

rule of law	-0.343	0.780	0.720	0.350	0.780	0.334	0.725	-0.677	-0.738	0.737		0.833	0.716	0.173		
control of corruption	-0.341	0.670	0.678	0.320	0.714	0.396	0.746	-0.581	-0.627	0.602	0.81	0.78	0.833		0.609	0.221
overall economic freedom score	-0.264	0.618	0.636	0.210	0.620	0.124	0.623	-0.479	-0.508	0.446	0.705	0.813	0.720	0.609		0.101
women MPs (% of all MPs)	-0.205	0.180	0.326	0.114	0.268	0.335	0.369	0.129	-0.125	0.104	0.269	0.230	0.173	0.221	0.101	

- education expenditure % of GDP
- education expenditure per person
- political stability & absence of violence
- regulatory quality
- rule of law
- control of corruption
- overall economic freedom score
- women MPs (% of all MPs)

Negatively correlated with -

- GINI Index
- political rights score
- civil liberties score

relation coefficient 5

0.0	0.0	* Pearson coefficients measure the strength and direction of the linear relationship between the two variables
0.1	0.1	
0.2	0.2	
0.3	0.3	
0.4	0.4	
0.5	0.5	-1 → perfect negative correlation
0.6	0.6	0 → no correlation
0.7	0.7	
0.8	0.8	
0.9	0.9	1 → perfect positive correlation
1.0	1.0	

* a variable correlated with itself will always have a correlation coefficient of 1.

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May 2022

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Meaning of colors across cultures

	Western/ American	Japanese	Hindu	Native American	Chinese	Asian	Eastern European	Muslim	African	South American
Anger	Red	Red	Black				Red		Red	
Art / Creativity	Grey	Grey	Blue							
Authority	Black	Grey								
Bad Luck	Grey	Black								
Balance		Orange		Black		Green				
Beauty	Purple									
Calm	Grey									
Celebration	Grey	Purple			Black					
Children	Pink	Pink								
Cold	Blue	Blue		Blue						
Compassion	Grey	Grey	Green							
Courage	Red	Yellow	Orange				Red			
Cowardice	Yellow	Yellow								
Cruelty	Purple									
Danger	Red	Red		Yellow					Red	
Death	Black	Black		Black	White		Blue		Green	
Decadence	Purple	Purple								
Deceit	Grey	Yellow								
Desire	Red	Red	Orange							
Earthy	Brown	Grey			Brown					
Energy	Yellow	Orange	Red							



chroma.js

chroma.js is a [small-ish](#) zero-dependency JavaScript library ([13.5kB](#)) for all kinds of color conversions and color scales.

build passing

Quick-start

Here are a couple of things chroma.js can do for you:

- read colors from a wide range of formats
- analyze and manipulate colors
- convert colors into wide range of formats
- linear and bezier interpolation in different color spaces

Here's an example for a simple read / manipulate / output chain:

```
chroma('pink').darken().saturate(2).hex()
```

"#ff6d93"

Aside from that, chroma.js can also help you [generate nice colors](#) using various methods, for instance to be [used](#) in color palette for maps or data visualization.

```
chroma.scale(['#fafa6e', '#2A4858'])
.mode('lch').colors(6)
```



health expenditure % of GDP	-0.178	0.236	0.304		0.408	0.282	0.381	-0.310	-0.429	0.243	0.235	0.273	0.350	0.320	0.210	0.114
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political rights score								0.947	-0.694	-0.545	-0.637	-0.677	-0.581	-0.479	-0.129	
rule of law								-0.71	-0.647	-0.684	-0.738	-0.627	-0.508	-0.125		
civil liberties score								-0.601	-0.711	-0.706	-0.645	-0.759	-0.662	-0.446	-0.104	
control of corruption								-0.595	-0.647	-0.706	-0.645	-0.781	-0.810	-0.705	-0.269	
overall economic freedom score								-0.634	-0.684	-0.645	-0.781	-0.833	-0.716	-0.173		
women MPs (% of all MPs)								-0.205	0.180	0.326	0.114	0.268	0.385	0.369	0.129	-0.125

Session 2e

Wrap up

- education expenditure % of GDP
- education expenditure per person
- political stability & absence of violence
- regulatory quality
- rule of law
- control of corruption
- overall economic freedom score
- women MPs (% of all MPs)

- Negatively correlated with -

- GINI Index
- political rights score
- civil liberties score

(Pearson Correlation coefficient S)

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-0.5	-0.5	0.5	0.5
-0.4	-0.4	0.6	0.6
-0.3	-0.3	0.7	0.7
-0.2	-0.2	0.8	0.8
-0.1	-0.1	0.9	0.9
0.0	0.0	1.0	1.0

* Pearson coefficients measure the strength and direction of the linear relationship between the two variables

-1 → perfect negative correlation

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Take home messages:

- Color = hue + lightness + saturation
 - Choose a color scale that fits your data
 - Avoid rainbow color palettes
 - Test your color palettes for colorblindness
-
- Whatever increases accessibility for some fraction of the population, increases accessibility overall.

Further reading

- Wong, Bang. "Points of view: Color blindness." (2011): 441.
- Tamara Munzner: Visualization Analysis and Design, 2016; Chapter 10: Map Color and Other Channels
- <https://www.color-blindness.com/types-of-color-blindness>
- Colin Ware: Information Visualization—Perception for Design, 2012