

# A Primer on Data Visualization

PSA Workshop on Data Visualization for Better Decision-Making  
June 5, 2023

**Dr. Michael Aupetit**

Senior Scientist at [Qatar Computing Research Institute HBKU](#)

Thank you **Dr. Ahmad Hussein** and **Ms. Sana Ahmad**  
for the invitation to give this presentation.

# QUIZ: What is data visualization?

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- It's about pictures

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- It's about pictures

- Like these ones?



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- Like these ones?

- No! Artificial pictures!



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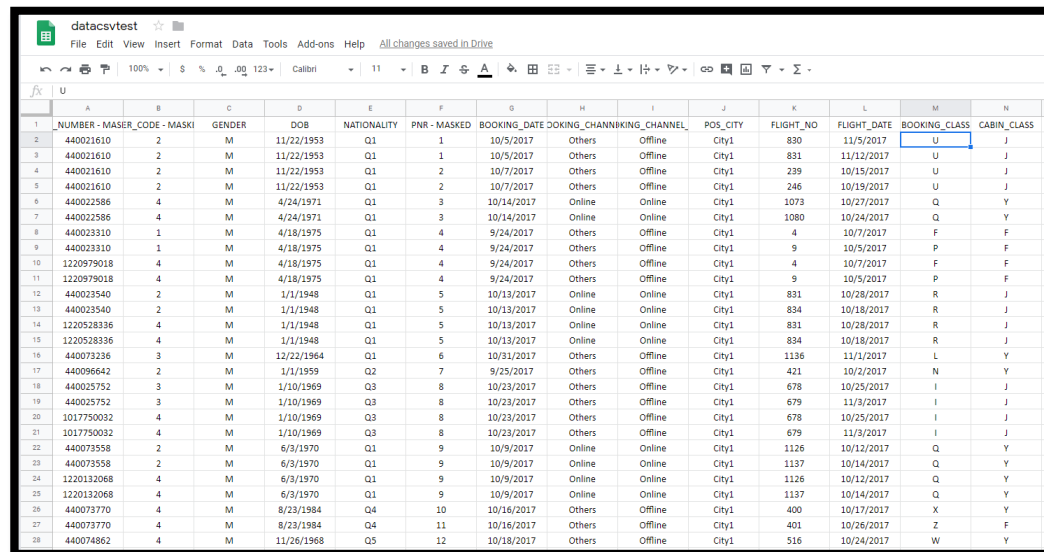
- No! Artificial pictures!
- Like these ones?
- Well, no! It is also about data!



# QUIZ: What is data visualization?

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- You mean like data sheets?



The screenshot shows a Google Sheets spreadsheet with the following data:

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
	NUMBER - MASER_CODE - MASKI	GENDER	DOB	NATIONALITY	PNR - MASKED	BOOKING_DATE	DOKING_CHANNEL	BOOKING_CHANNEL	POS_CITY	FLIGHT_NO	FLIGHT_DATE	BOOKING_CLASS	CABIN_CLASS	
1	440021610	2	M	11/22/1953	Q1	1	10/5/2017	Others	Offline	City1	830	11/5/2017	U	J
2	440021610	2	M	11/22/1953	Q1	1	10/5/2017	Others	Offline	City1	831	11/12/2017	U	J
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6	440022586	4	M	4/24/1971	Q1	3	10/14/2017	Online	Online	City1	1080	10/24/2017	Q	Y
7	440023310	1	M	4/18/1975	Q1	4	9/24/2017	Others	Offline	City1	4	10/7/2017	F	F
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9	1220979018	4	M	4/18/1975	Q1	4	9/24/2017	Others	Offline	City1	4	10/7/2017	F	F
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16	440096642	2	M	1/1/1959	Q2	7	9/25/2017	Others	Offline	City1	421	10/2/2017	N	Y
17	440025752	3	M	1/10/1969	Q3	8	10/23/2017	Others	Offline	City1	678	10/25/2017	I	J
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19	1017750032	4	M	1/10/1969	Q3	8	10/23/2017	Others	Offline	City1	678	10/25/2017	I	J
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25	440073770	4	M	8/23/1984	Q4	10	10/16/2017	Others	Offline	City1	400	10/17/2017	X	Y
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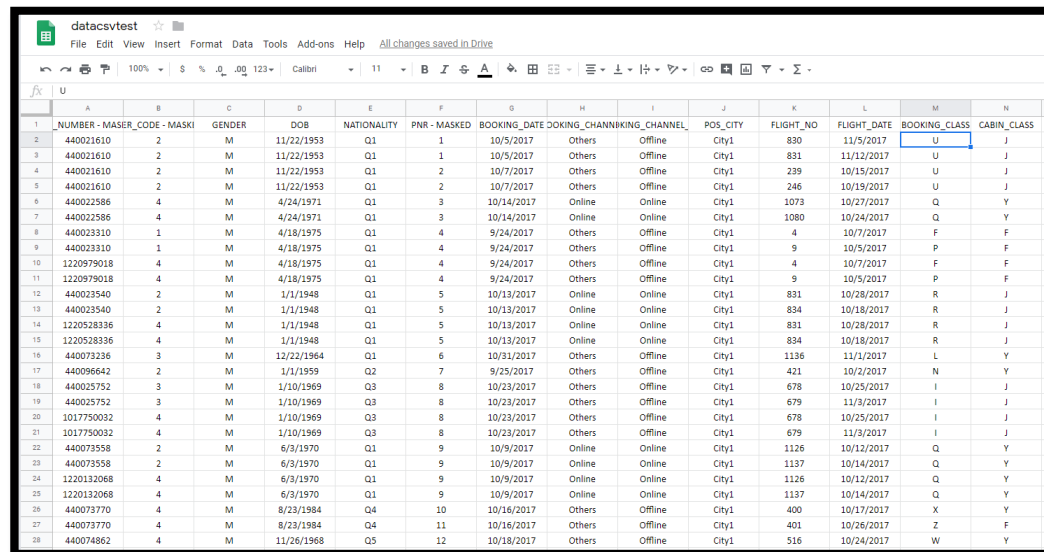


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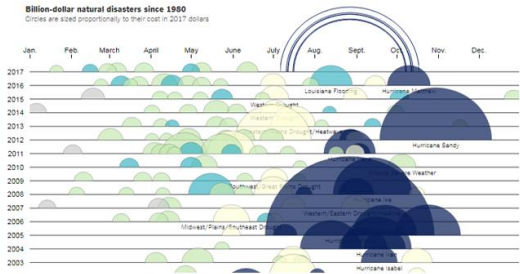
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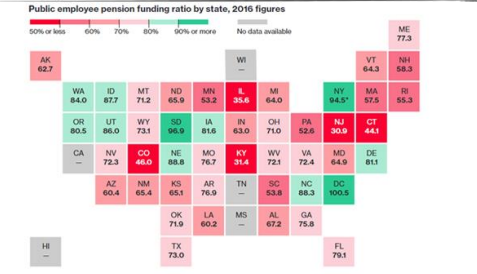
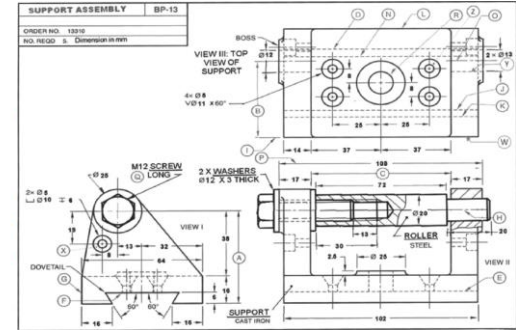
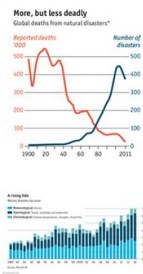
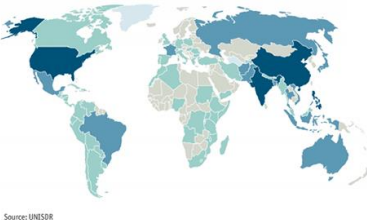
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Team	Player	Salary	Pos	Order	Team	Opp	wOBA	uOBA	DIFF	ISO	OOP	SLG	SOBAB	WARAB	SBAC	Pre	My	Warp	Bargain	ParFk	Rate	Opp	Run	ML	QW	ML%
78.26	Eduardo Nunez (R)	\$300	RFO5	16	MIA	BOYT + Rodriguez (R)	0.534	0.527	0.175	0.482	0.432	0.133	0.034	0.216	7	0	0	0	Hunter Wendt	18	17	3.8	3.2	129	103	21
78.18	Tanner Plam (R)	\$180	OF	10	SD	1D + Tankowski (R)	0.401	0.053	0.268	4.112	0.588	0.322	0.053	0.016	10	0	0	0	Alexander Wang	19	17	3.8	3.4	113	9	26
76.18	Miguel Sano (R)	\$440	1B/OF	10	MIN	BOYT + Rodriguez (R)	0.547	0.064	0.331	0.545	0.427	0.411	0.015	0.015	7	0	0	0	Hunter Wendt	19	19	3.8	3.2	129	103	21



Disaster zones  
Total number of natural disasters\* reported per country, 1995-2015



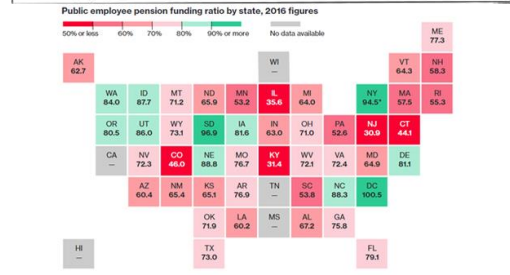
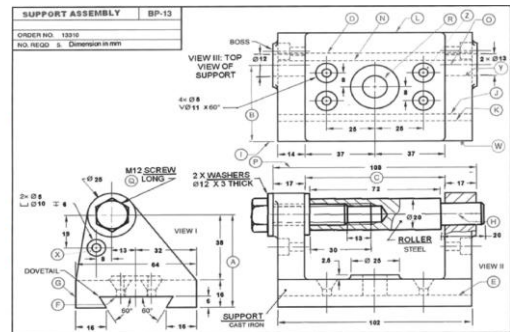
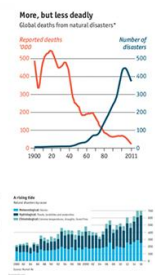
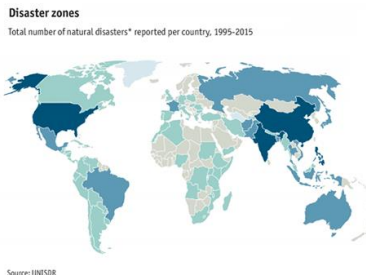
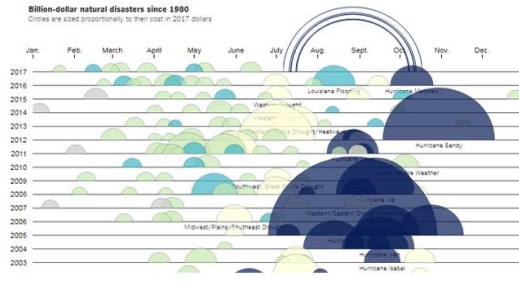
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Support		StatKing	FanDuel	Yahoo	Baseball	Pitchers	C	1B	2B	3B	SS	OF
Pos	Team	Salary	Rate	Rate	Rate	Rate	Rate	Rate	Rate	Rate	Rate	Rate
LF	Edgar Renteria (R)	\$3000	30.5%	16	MI	BOYD - F Rodriguez (R)	0.334	0.023	0.125	0.000	0.432	0.133
LF	Tony Blum (R)	\$1800	18.0%	10	SD	TD - Jankowski (R)	0.402	0.053	0.286	0.112	0.588	0.322
LF	Miguel Sano (R)	\$4400	44.0%	18	MIN	BOYD - F Rodriguez (R)	0.347	0.044	0.231	0.045	0.487	0.411
LF	Jan Denard (R)	\$1800	18.0%	20	TEX	BLAA - G Pezz (R)	0.342	0.074	0.186	0.048	0.483	0.294
LF	Carlos Santana (R)	\$4900	49.0%	18	DET	BNH - A Miller (R)	0.348	0.021	0.232	0.046	0.519	0.347
LF	Willy Vacheco (R)	\$4100	41.0%	30	BAL	BNH - A Miller (R)	0.344	0.037	0.201	0.037	0.482	0.186
LF	Jan Kriver (R)	\$4700	47.0%	28	DET	MIN - T Rogers (R)	0.417	0.073	0.236	0.033	0.599	0.513
LF	Garrett Buckham (R)	\$3600	36.0%	16	ATL	BNH - A Miller (R)	0.332	0.031	0.154	0.048	0.344	0.189
LF	Justin Porter (R)	\$3300	33.0%	18	TEX	BLAA - G Pezz (R)	0.413	0.011	0.253	0.045	0.579	0.194
LF	Carlos Beltran (R)	\$3200	32.0%	30	NY	BAL - D Hays (R)	0.376	0.015	0.236	0.038	0.361	0.177
LF	Adriano Diaz (R)	\$4800	48.0%	35	SD	TD - Jankowski (R)	0.393	0.046	0.234	0.040	0.515	0.348
LF	Logan Forsythe (R)	\$3100	31.0%	18	SD	BNH - A Miller (R)	0.315	0.013	0.124	0.039	0.383	0.225
LF	Stephen Piscotty (R)	\$3200	32.0%	16	SD	TD - Jankowski (R)	0.348	0.017	0.117	0.031	0.483	0.212
LF	Marlon Gonzalez (R)	\$3400	34.0%	28	HOU	BNH - A Miller (R)	0.321	0.035	0.158	0.040	0.481	0.227
LF	Dark Carron (R)	\$4900	49.0%	35	ATL	E O'Day (R)	0.349	0.028	0.283	0.112	0.533	0.516
LF	Dan Lajoie (R)	\$3900	39.0%	38	SD	BNH - A Miller (R)	0.327	0.036	0.212	0.044	0.472	0.225
LF	George Springer (R)	\$4400	44.0%	30	HOU	BNH - A Miller (R)	0.334	0.054	0.181	0.029	0.438	0.224
LF	Charlie Blackmon (R)	\$4900	49.0%	30	COL	TR - O Arica (R)	0.348	0.006	0.171	0.042	0.487	0.518
LF	Adam Jones (R)	\$4600	46.0%	30	BAL	BNH - A Miller (R)	0.295	0.019	0.118	0.033	0.333	0.207
LF	Scott Holtby (R)	\$3500	35.0%	30	SD	TD - Jankowski (R)	0.338	0.028	0.136	0.043	0.446	0.189
LF	Adam Duvalier (R)	\$4800	48.0%	30	MIN	ATL - E O'Day (R)	0.334	0.022	0.214	0.037	0.482	0.325
LF	Michael Anastos (R)	\$3500	35.0%	38	COL	TR - O Arica (R)	0.375	0.009	0.281	0.044	0.571	0.176
LF	Chris Bruntz (R)	\$4800	48.0%	30	MIN	ATL - E O'Day (R)	0.243	0.014	0.147	0.047	0.367	0.228



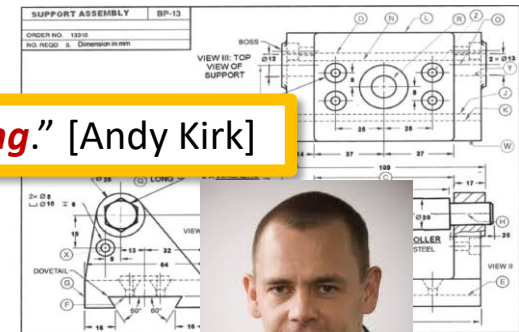
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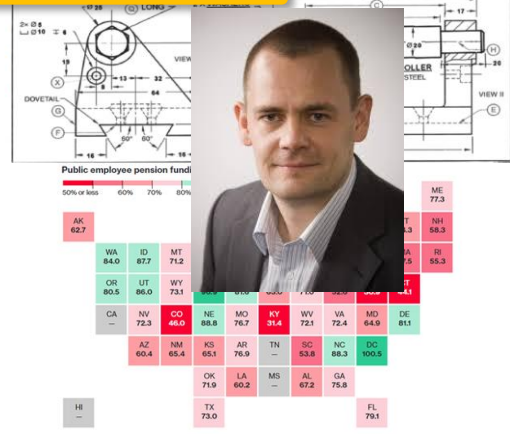
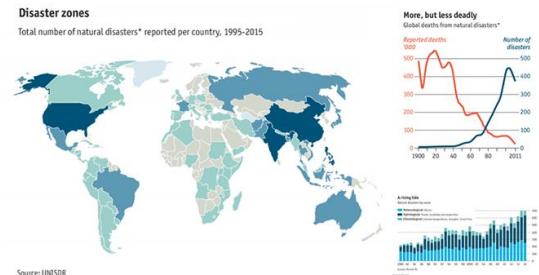
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Player	Team	Pos	Age	Height	Weight	Points	Rebounds	Assists	Steals	Blocks	Minutes	Field %	3Pt %	Free %	Points per game	Rebounds per game	Assists per game	Steals per game	Blocks per game
LeBron James	CLE	F	34	6'9"	250	27.1	6.5	6.2	1.5	1.0	36.0	50.5	37.1	78.1	27.1	6.5	6.2	1.5	1.0
Stephen Curry	GOLDEN STATE	G	33	6'2"	190	24.8	4.3	6.7	1.6	0.3	32.7	42.4	38.7	91.1	24.8	4.3	6.7	1.6	0.3
Kyle Kuzma	MEMPHIS	F	26	6'10"	230	17.6	5.5	1.9	0.4	0.2	28.1	47.8	32.1	17.6	5.5	1.9	0.4	0.2	0.2



**“The representation and presentation of *data* to *facilitate understanding*.” [Andy Kirk]**



# Why data visualization?

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$I_1$	20	19
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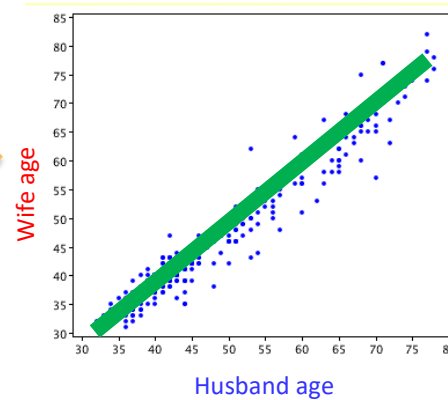


Aha!

$$\text{Wife age} = k_1 * \text{Husband age} + k_2$$

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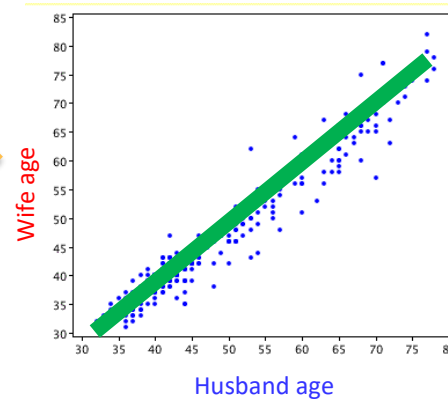
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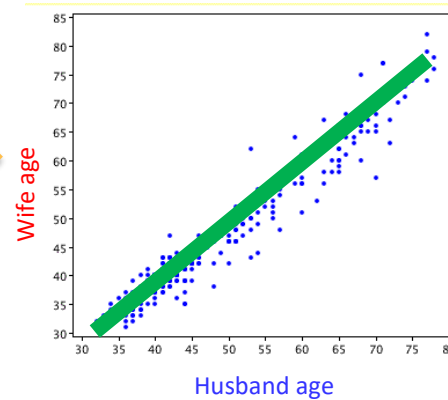
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- What is Data Visualization?
- User Centered Design
- Visual Perception
- Criteria for Good Visualizations
- Some examples
- Resources

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- Umbrella for many sciences and techniques related to images

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## Real world





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Real world



Image



Image Processing

improve image quality



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Real world

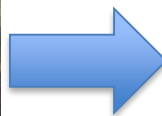


Image



**Image Processing**

improve image quality



**Computer Vision**

Image analysis

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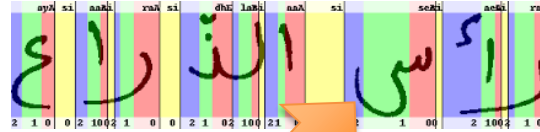
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Real world

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**Computer Vision**  
Image analysis

**Computer Graphics**  
Image rendering



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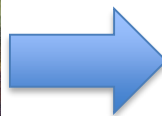
Real world



Image



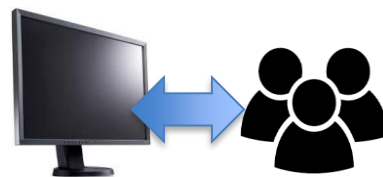
**Image Processing**  
improve image quality



**Computer Vision**  
Image analysis



**Computer Graphics**  
Image rendering



**Human Computer  
Interaction**

Get real time user feedback  
to improve *understanding*

# Visual Computing

- Umbrella for many sciences and techniques related to images

Real world



Image



**Image Processing**

improve image quality



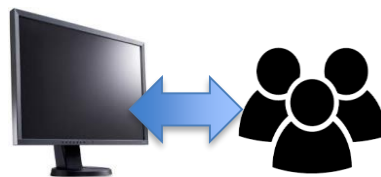
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**Virtual Reality**

Produce feeling of physical  
immersion in virtual world



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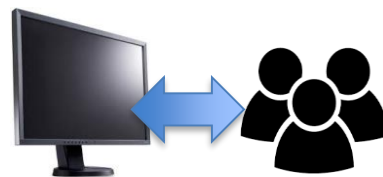


**Computer Vision**  
Image analysis



**Augmented Reality**  
Augment real world images  
with virtual objects

**Computer Graphics**  
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Image

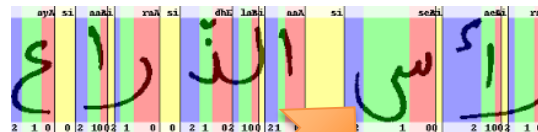


**Image Processing**  
improve image quality



**Computer Vision**

Image analysis

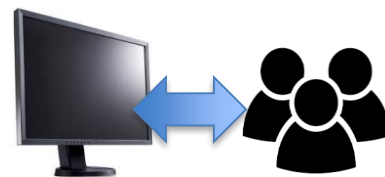


**Augmented Reality**

Augment real world images with virtual objects

**Computer Graphics**

Image rendering



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Data





# Visual Computing

- Umbrella for many sciences and techniques related to images

Real world



Data

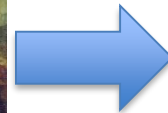


**Data Analytics**  
Transform data into meaningful insights

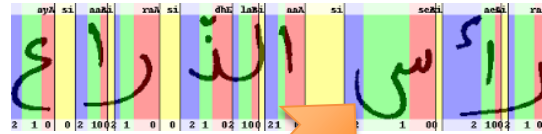
Image



**Image Processing**  
improve image quality



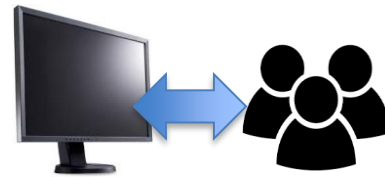
**Computer Vision**  
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**Computer Graphics**  
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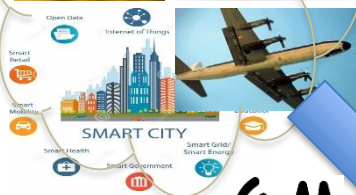
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Real world



Data



**Data Analytics**  
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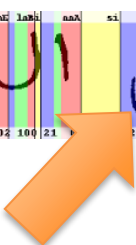
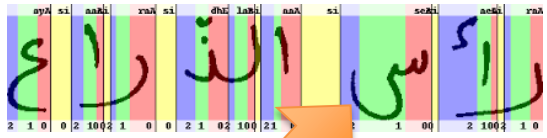
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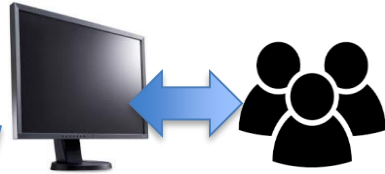
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**Human Computer Interaction**  
Get real time user feedback to improve *understanding*



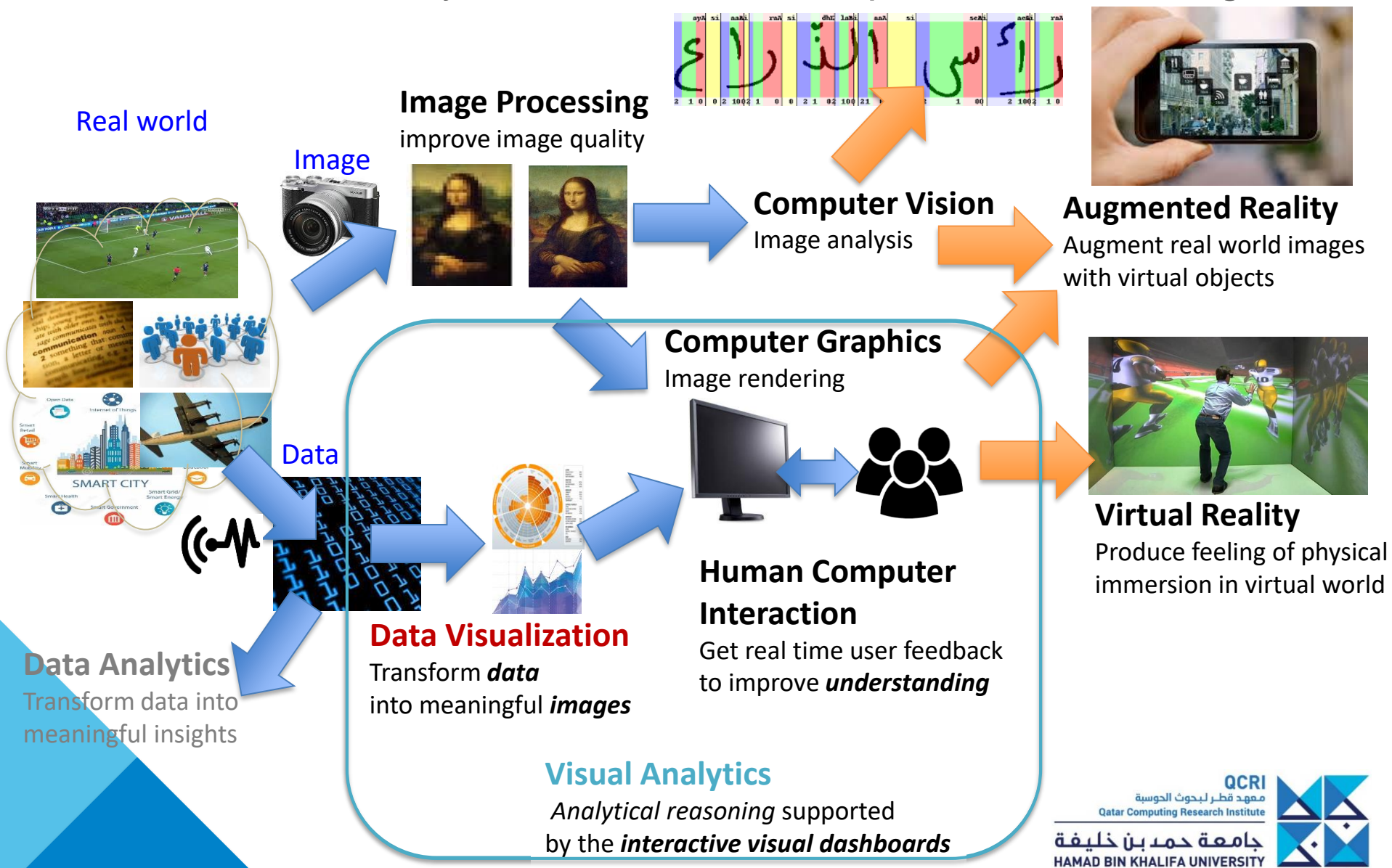
**Virtual Reality**  
Produce feeling of physical immersion in virtual world

**Data Visualization**  
Transform *data* into meaningful *images*



# Visual Computing

- Umbrella for many sciences and techniques related to images



# Visual Computing

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Real world



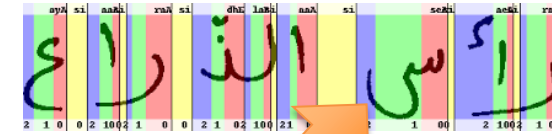
Data

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Transform data into meaningful insights

Image



**Image Processing**  
improve image quality

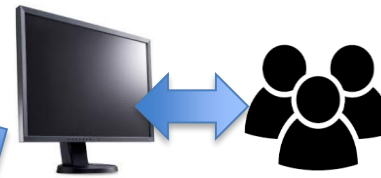


**Computer Vision**  
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**Virtual Reality**  
Produce feeling of physical immersion in virtual world

**Data Visualization**  
Transform *data* into meaningful *images*



**Visual Analytics**

Analytical reasoning supported by the *interactive visual dashboards*

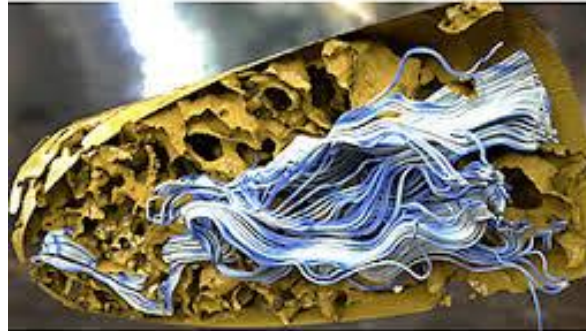
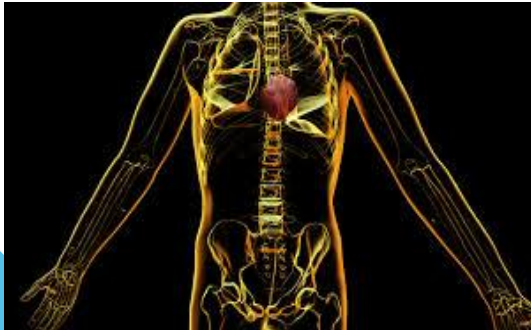
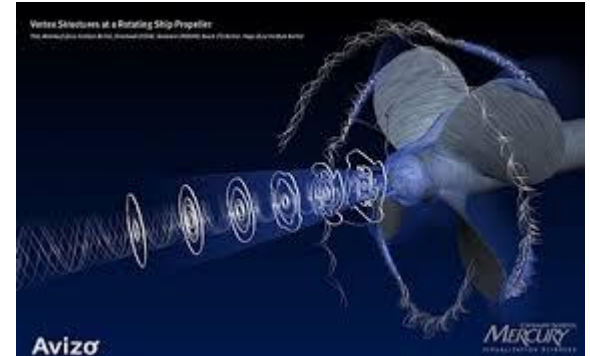
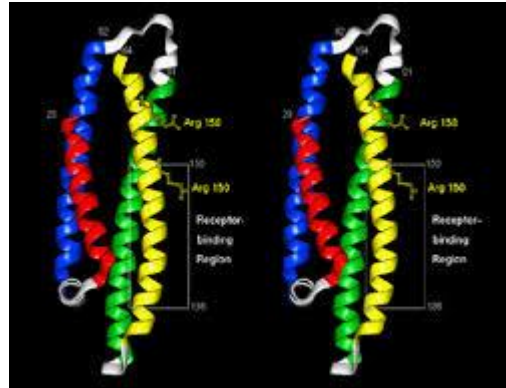
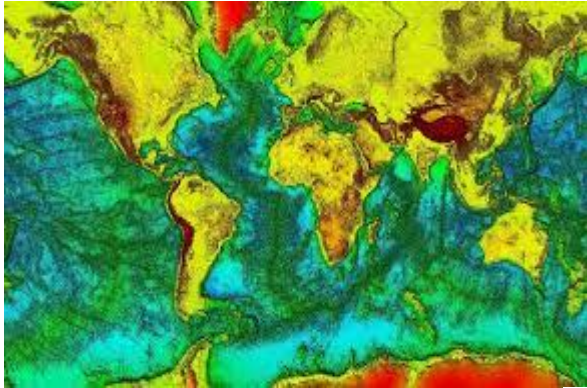


# Scientific Visualization (SciVis)

- Visualization of data with **natural x-y-z spatial coordinates**

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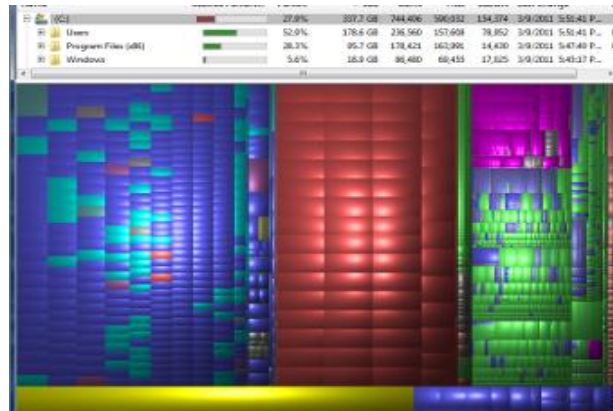
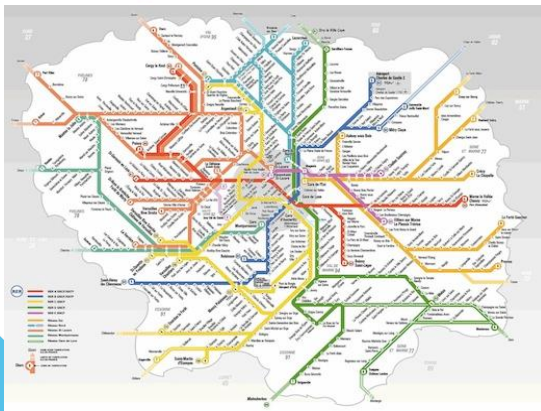
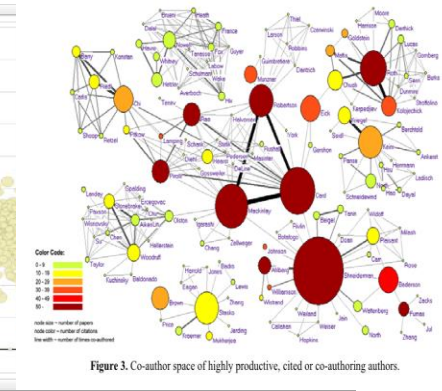
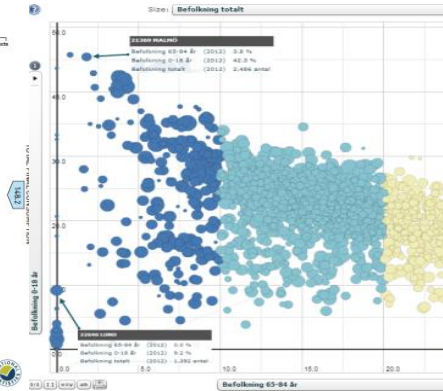
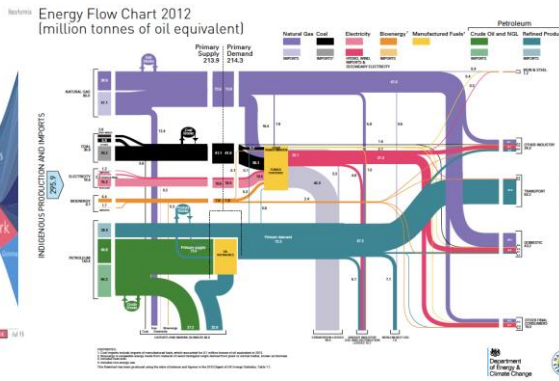
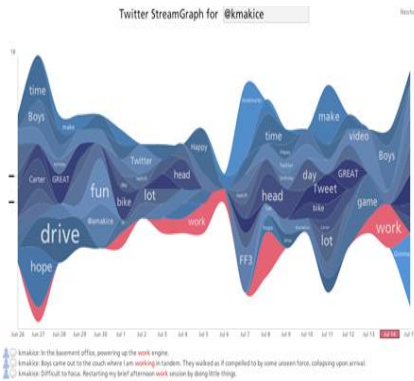


# Information Visualization (InfoVis)

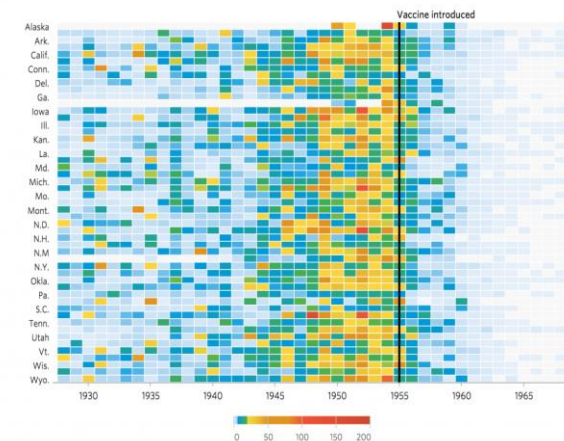
- Visualization of **abstract data** with not essential x-y-z meaning

# Information Visualization (InfoVis)

- Visualization of abstract data with not essential x-y-z meaning



Polio





# Data Visualization and Visual Analytics

- Data Visualization is a **component of Visual Analytics**, used for data exploration by a domain expert
- Designing Visual Analytic dashboards follows a **User-Centered Design** process

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Domain  
expert

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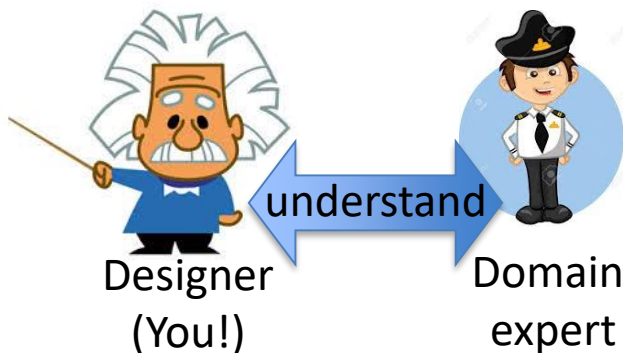
Designer  
(You!)



Domain  
expert

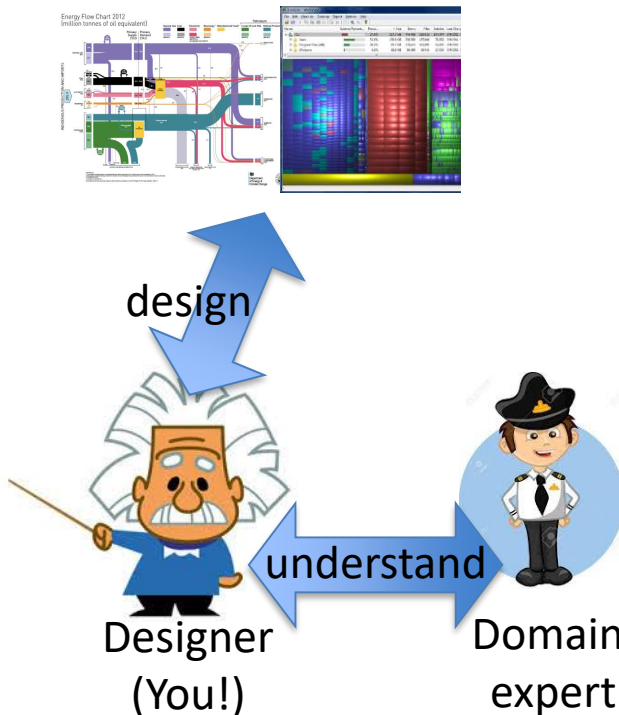
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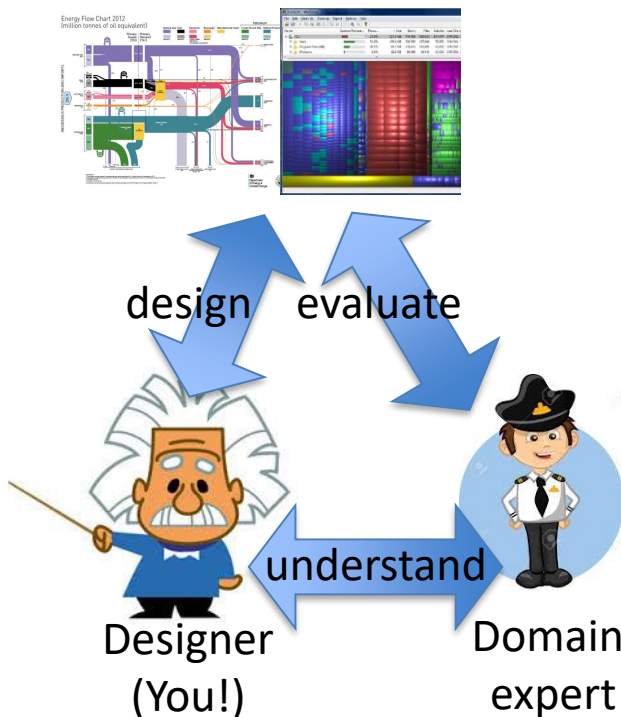
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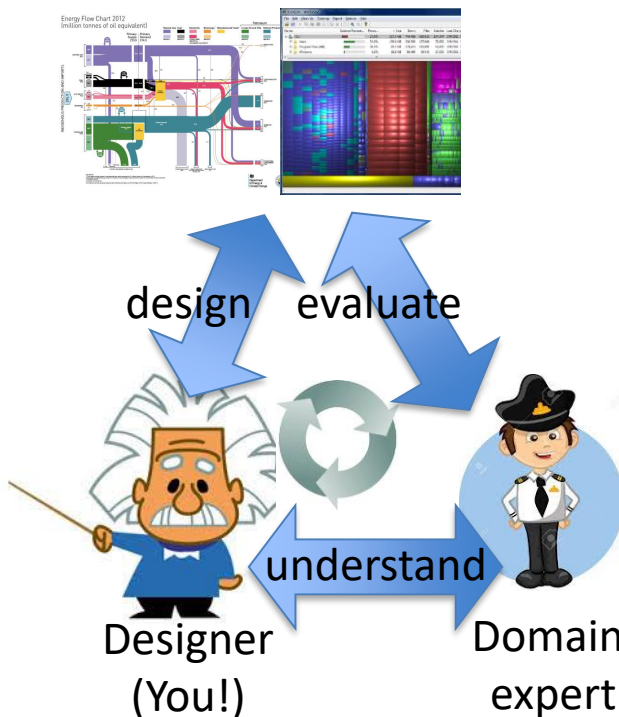
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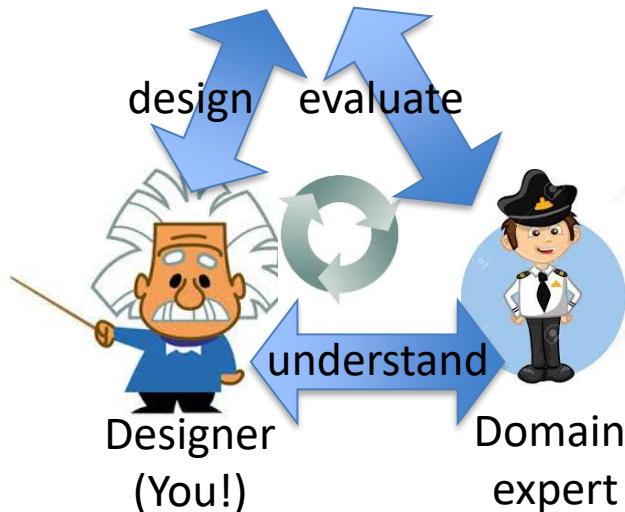
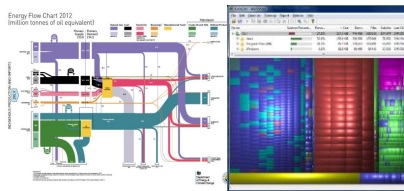
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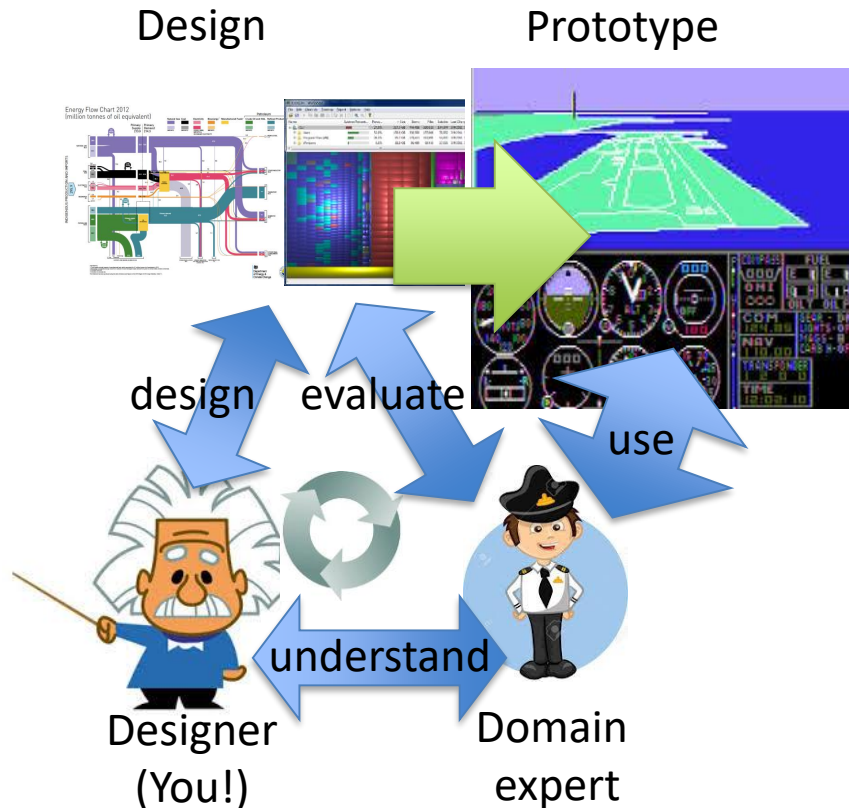
Design





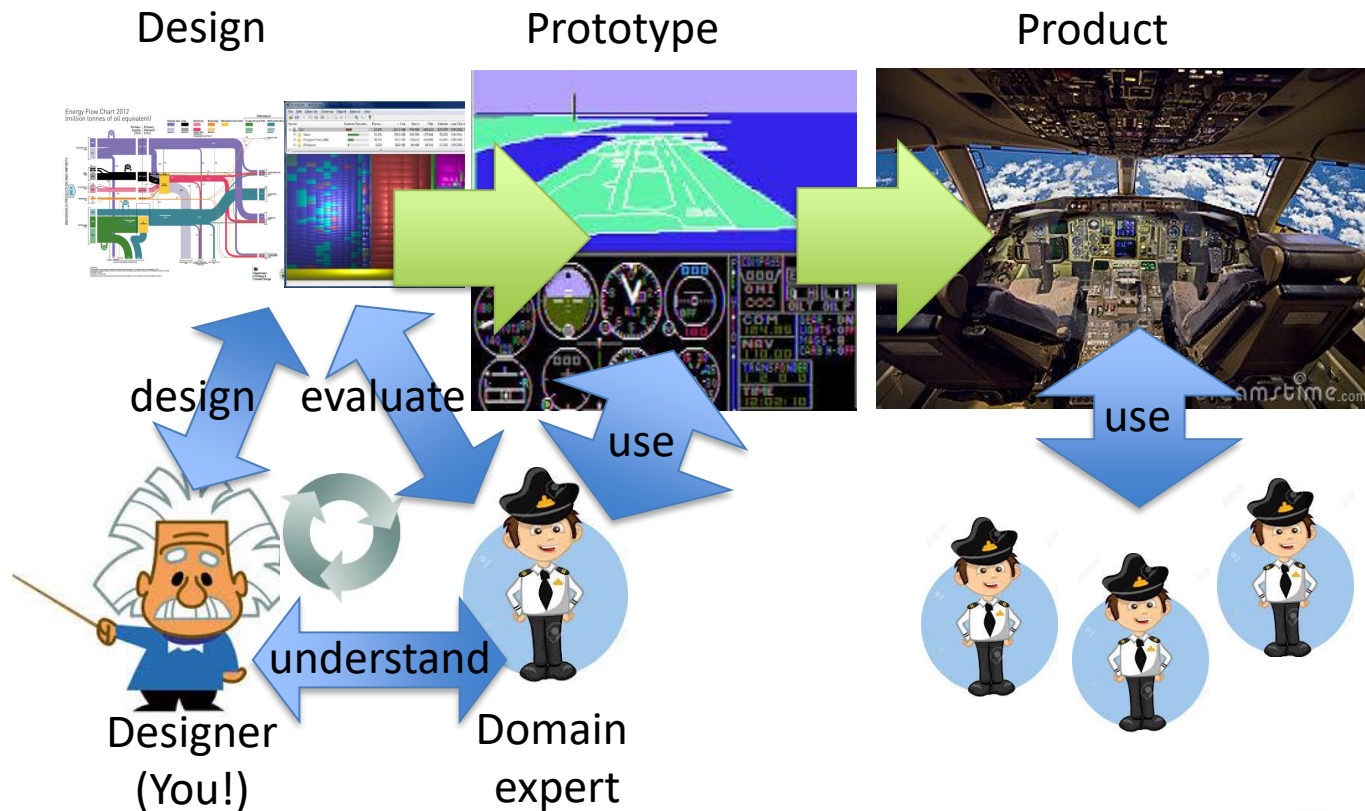
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# Outline

- What is Data Visualization?
- **User Centered Design**
- Visual Perception
- Criteria for Good Visualizations
- Some examples
- Resources

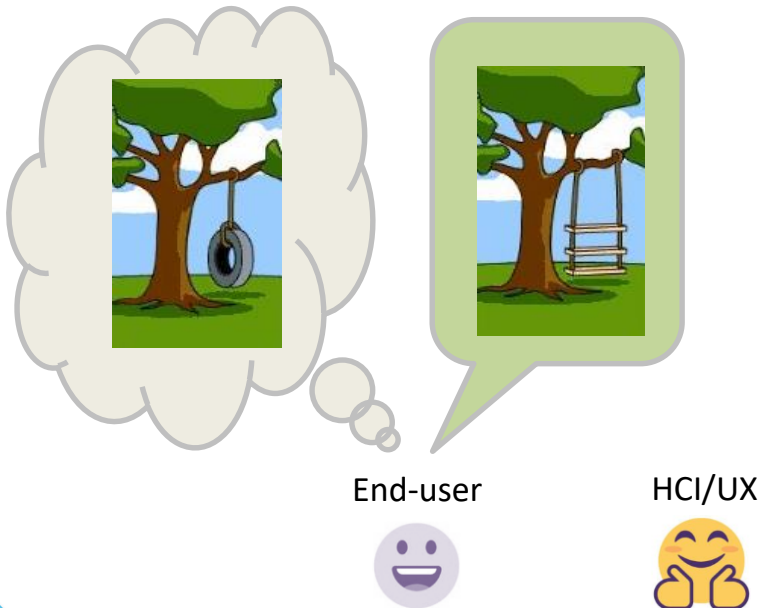
# User-Centered Design



End-user

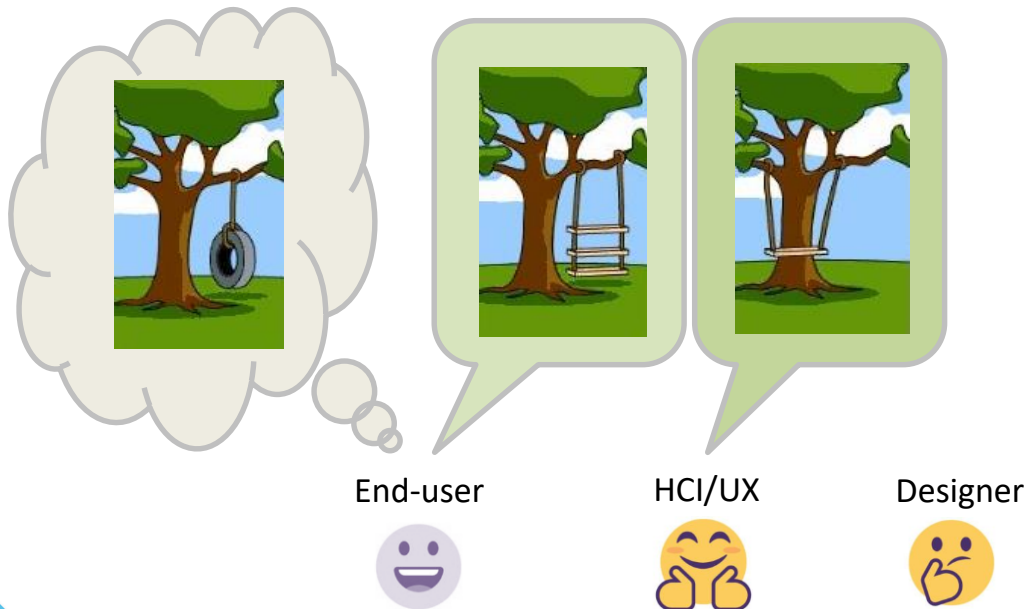


# User-Centered Design

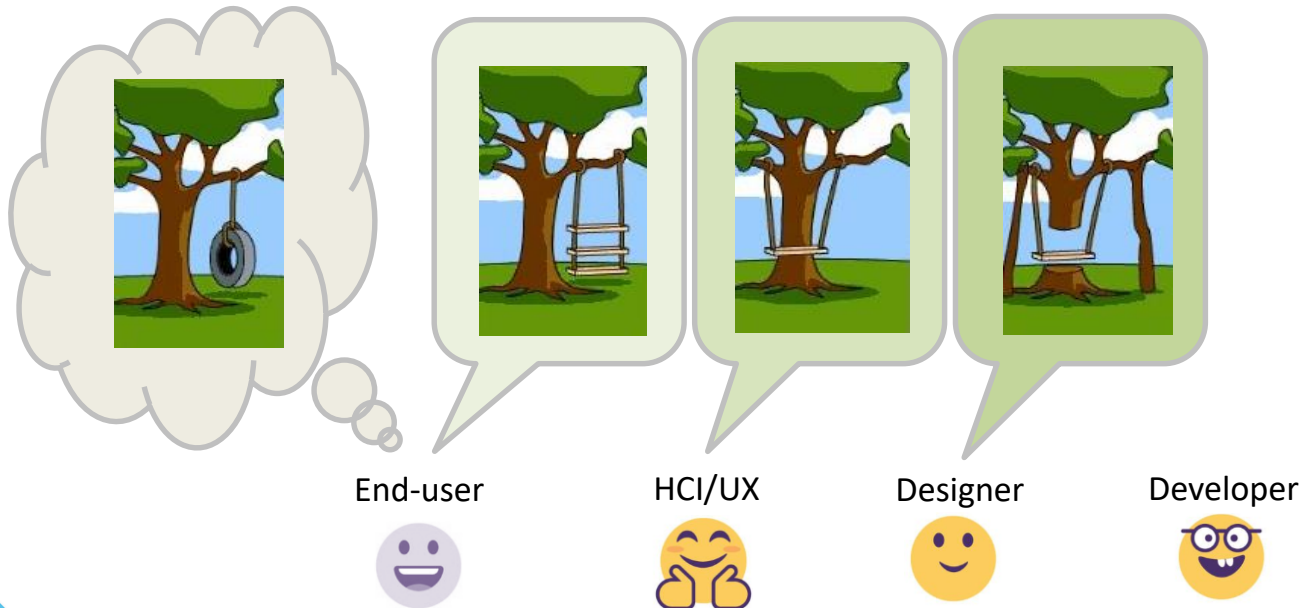


**HCI:** Human-Computer Interaction  
**UX:** User eXperience

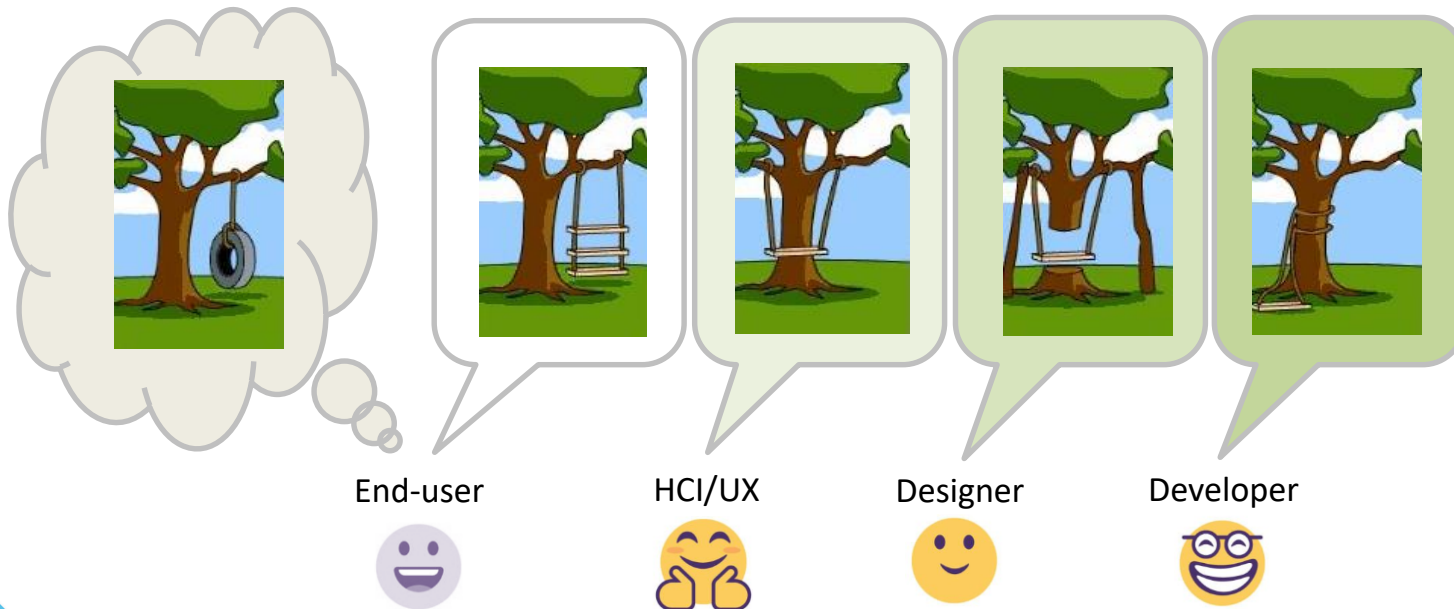
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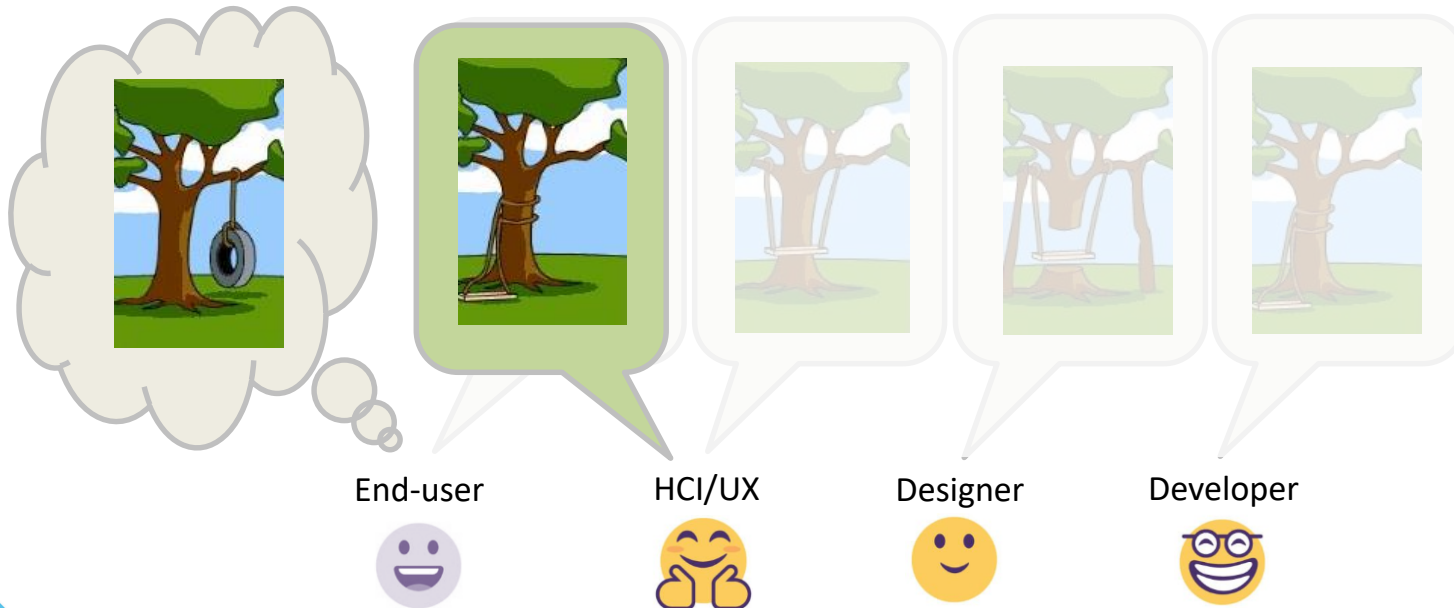


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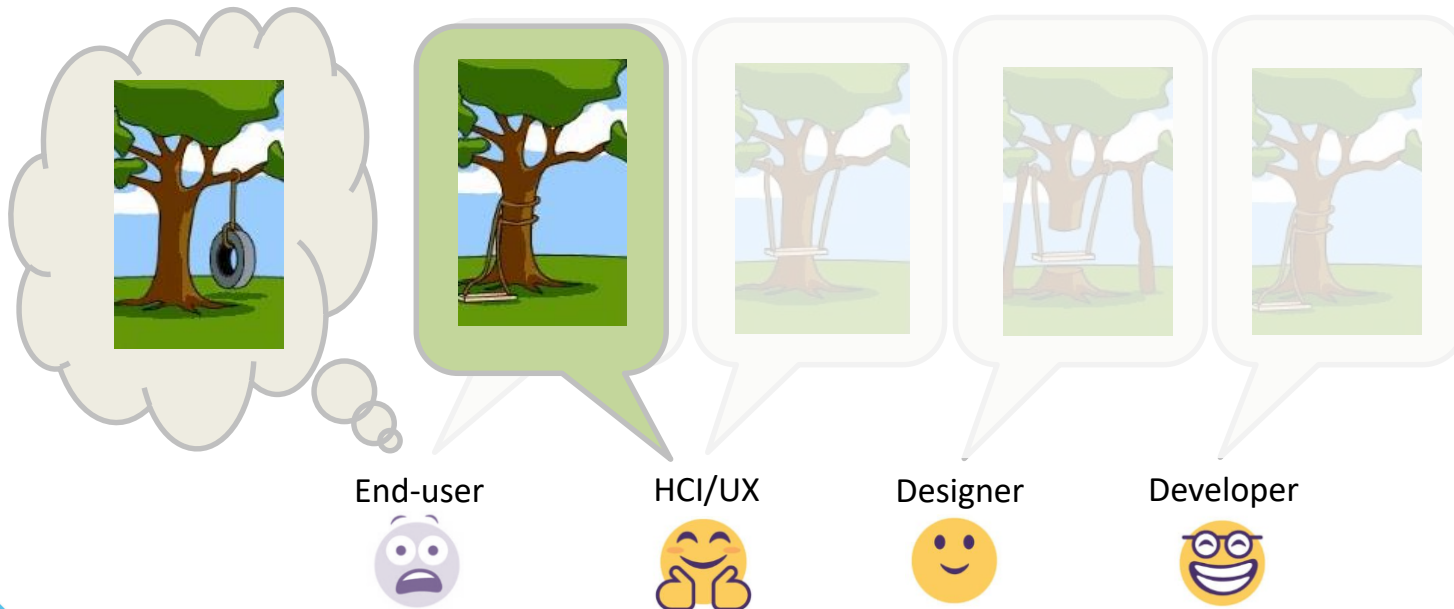




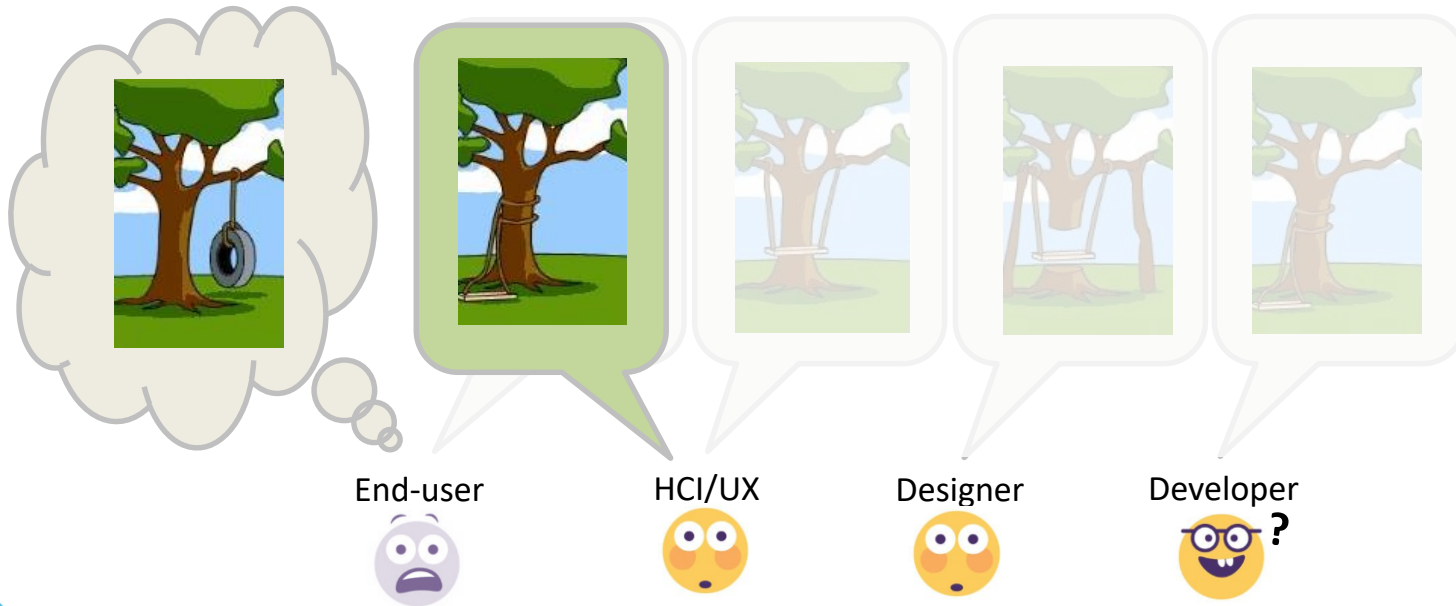
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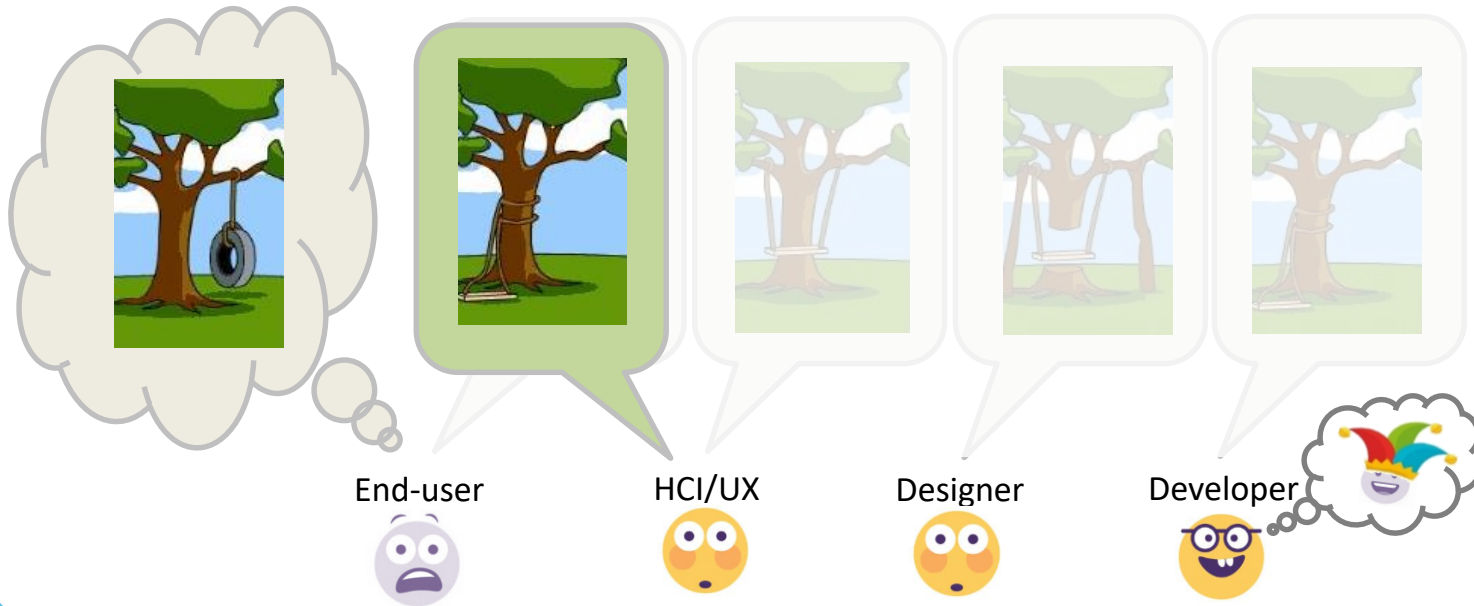
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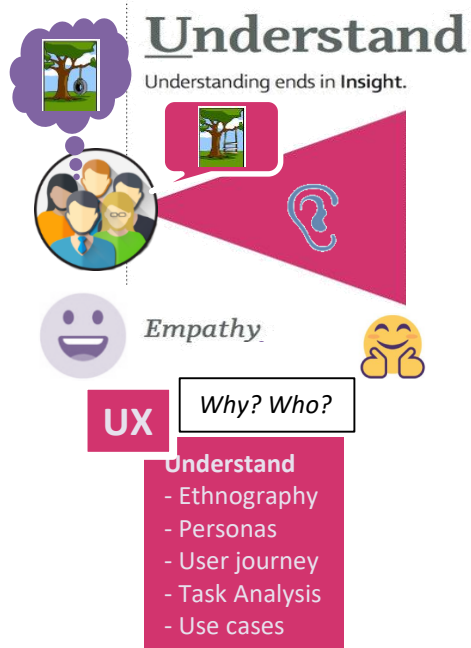
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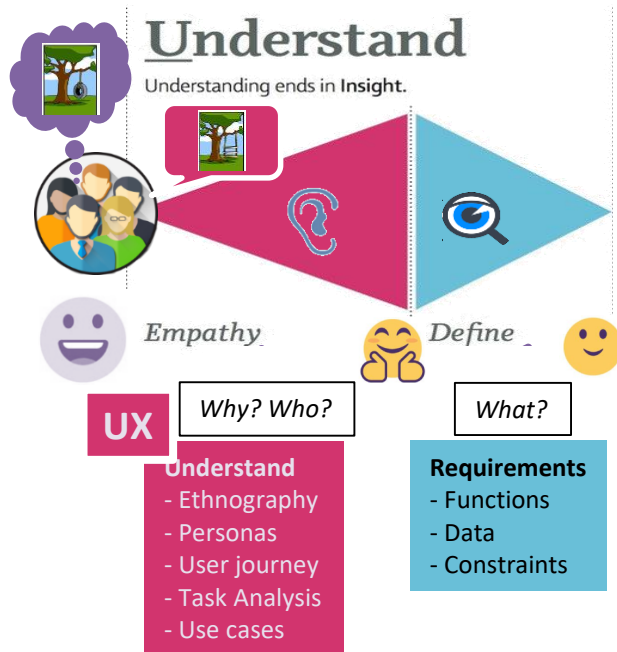


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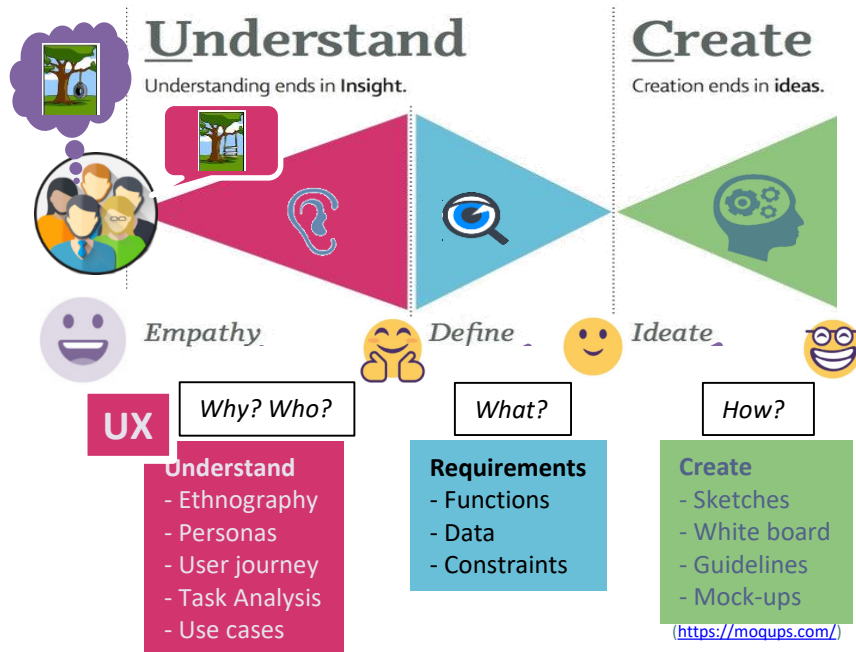
<https://medium.theuxblog.com/my-user-centered-design-mashup-defining-process-and-communicating-value-65df72f5648a>

# User-Centered Design



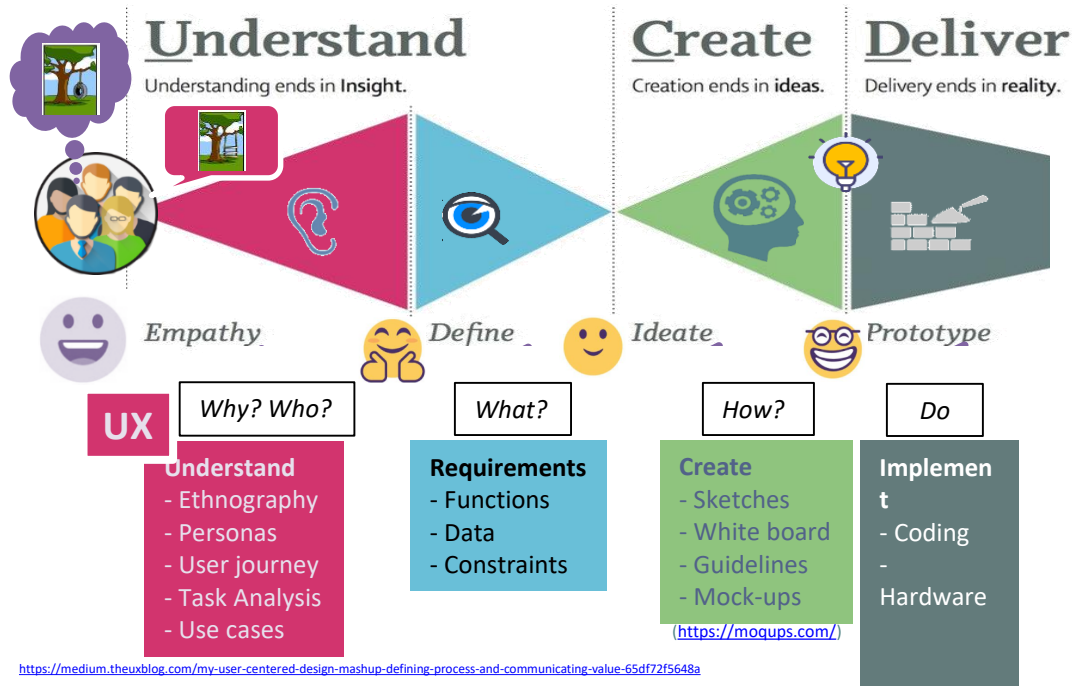
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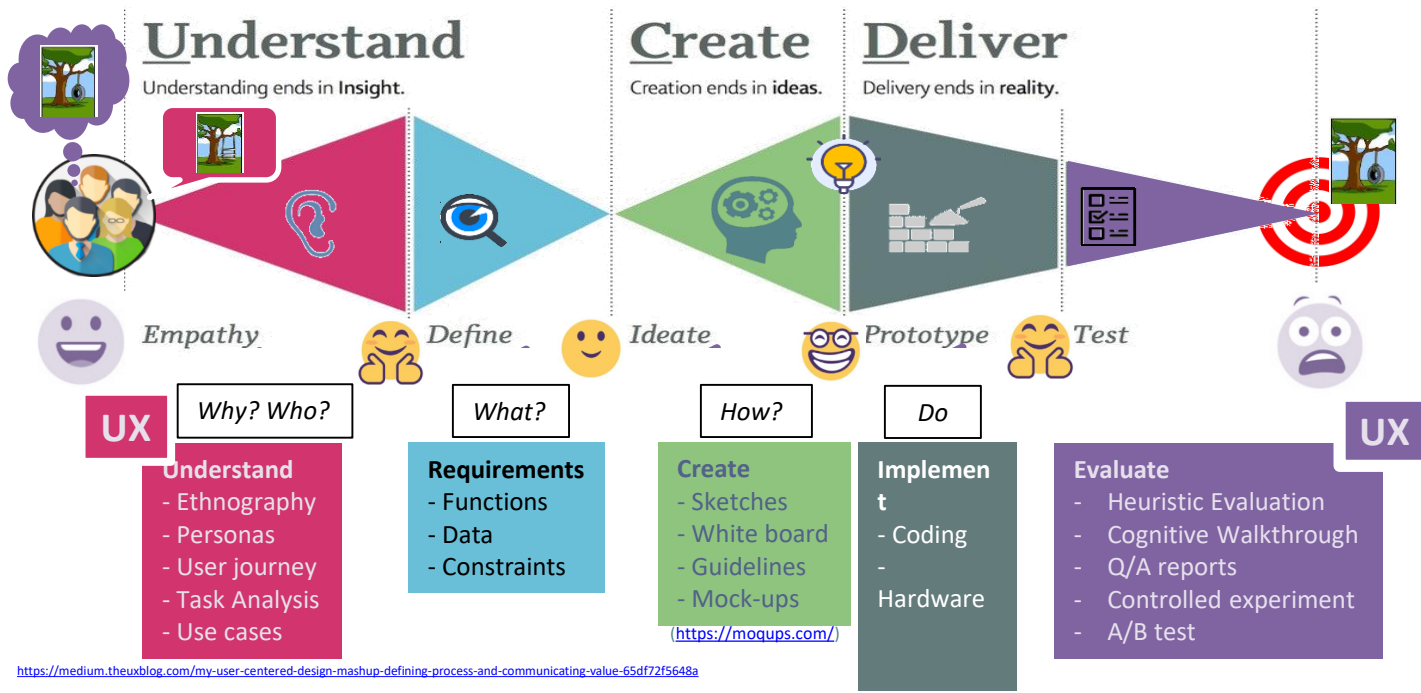
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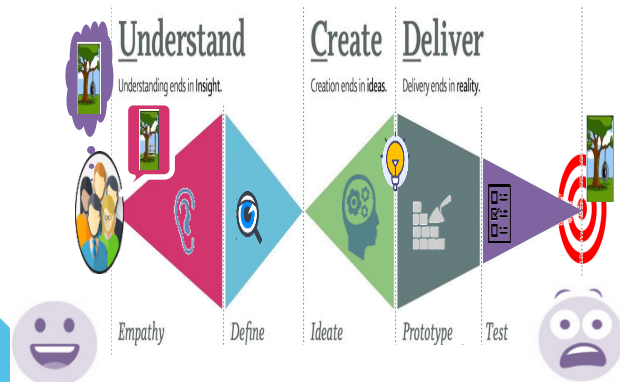


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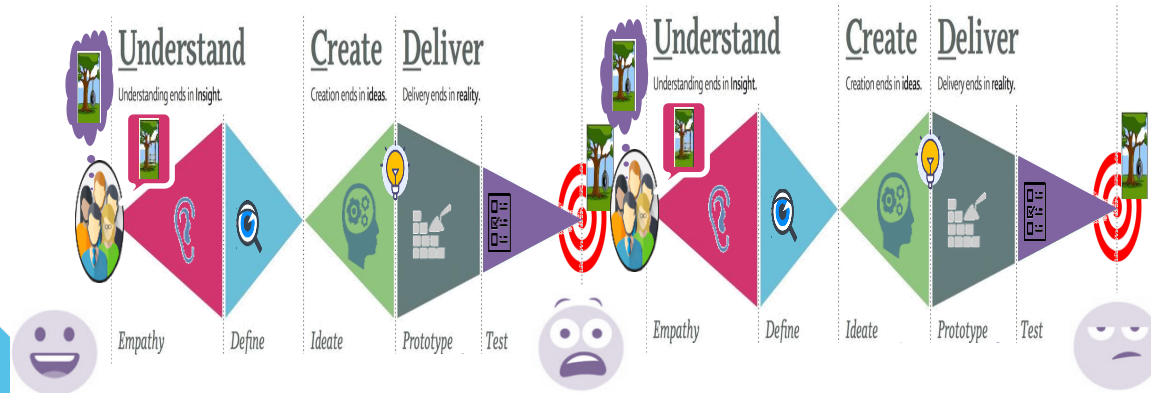


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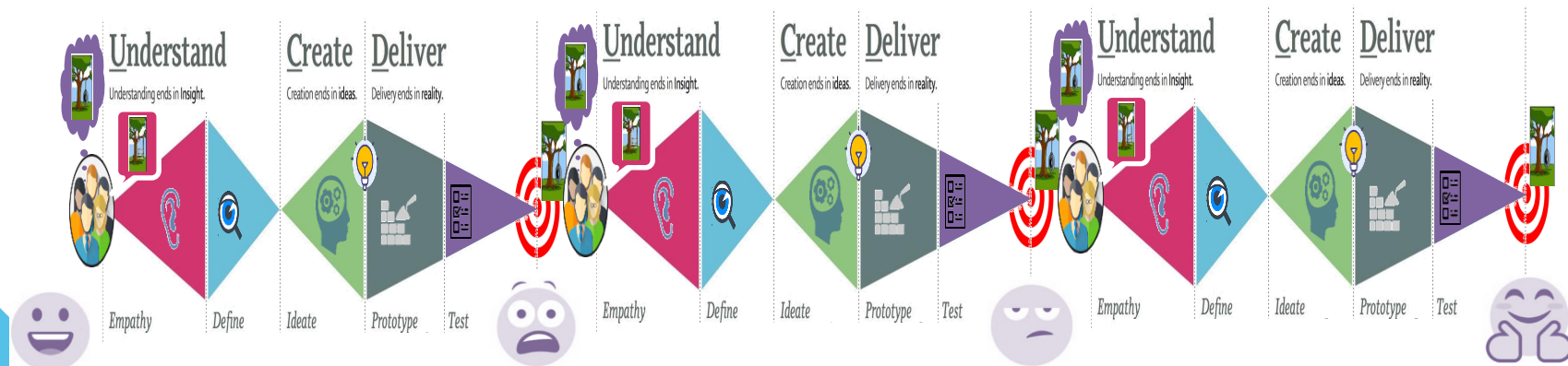
# User-Centered Design



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# Visualization purpose

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- **(Interactive) Visualization** is intended to support a **user** to achieve a **goal** related to some **data**

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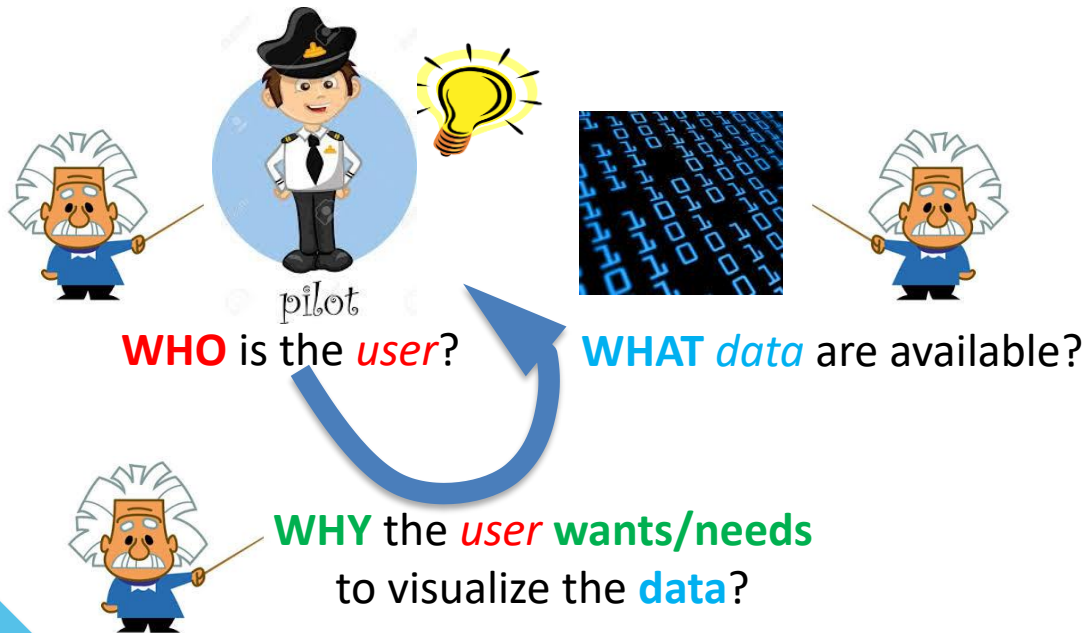
**WHO** is the *user*?



**WHAT** *data* are available?

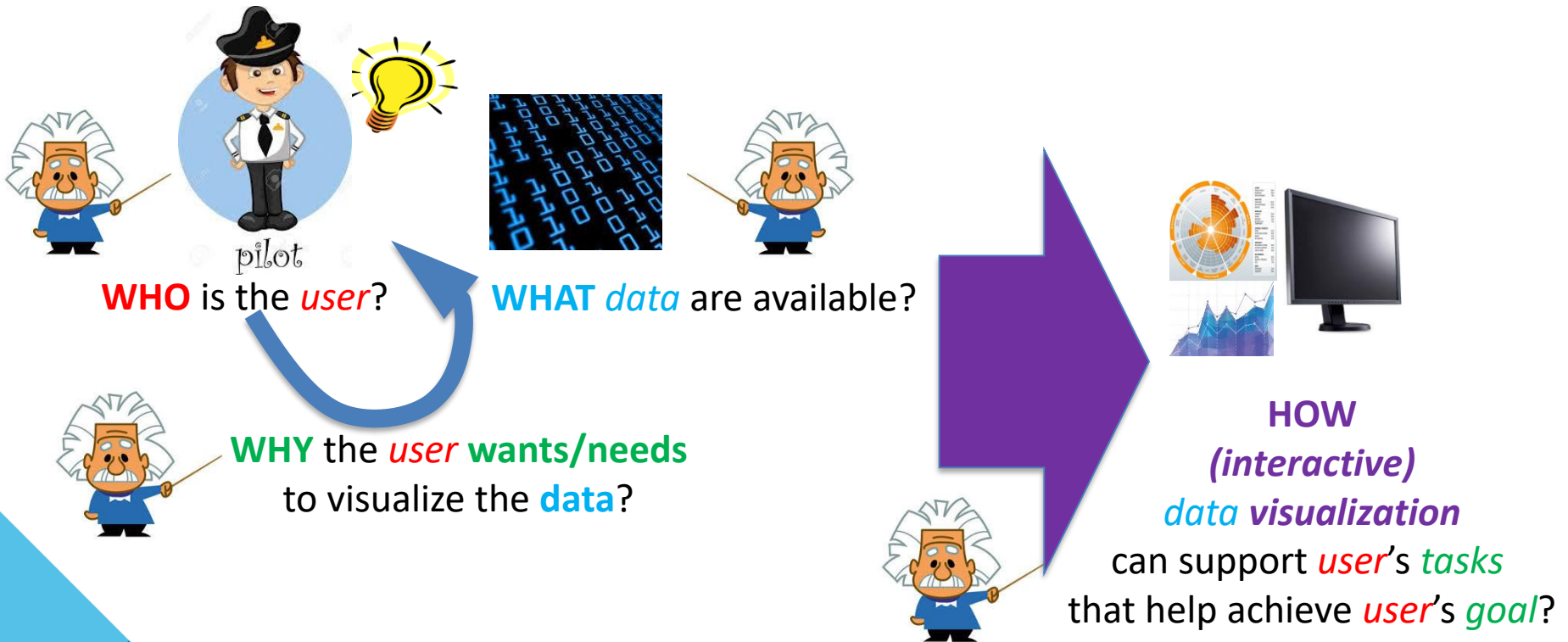
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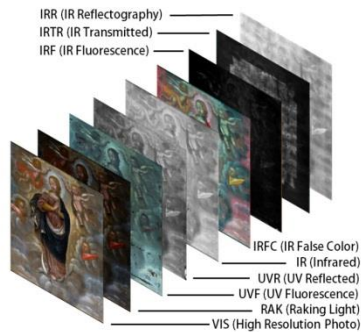
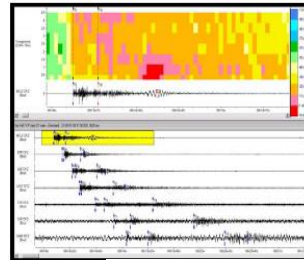
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# WHAT data are available

## Data types

- Tables
- Networks
- Images
- Signals
- Trees
- ...



	Product A	Product B	Product C	Product D	Product E
20M	2M	12M	2M	21M	
30M	4M	10M	8M	26M	
14M	3M	14M	9M	24M	
16M	5M	11M	4M	23M	
					2002
					2003
					2004

## Variable/Feature/Attributes

Name	Thread pitch (mm)	Minor diameter tolerance	Nominal diameter (mm)	Head shape	Price for 50 screws	Available at factory outlet?	Number in stock	Flat or Phillips head?
M4	0.7	4g	4	Pan	\$10.08	Yes	276	Flat
M5	0.8	4g	5	Round	\$13.89	Yes	183	Both
M6	1	5g	6	Button	\$10.42	Yes	1043	Flat
M8	1.25	5g	8	Pan	\$11.98	No	298	Phillips
M10	1.5	6g	10	Round	\$16.74	Yes	488	Phillips
M12	1.75	7g	12	Pan	\$18.26	No	998	Flat
M14	2	7g	14	Round	\$21.19	No	235	Phillips
M16	2	8g	16	Button	\$23.57	Yes	292	Both
M18	2.1	8g	18	Button	\$25.87	No	664	Both
M20	2.4	8g	20	Pan	\$29.09	Yes	486	Both
M24	2.55	9g	24	Round	\$33.01	Yes	982	Phillips
M28	2.7	10g	28	Button	\$35.66	No	1067	Phillips
M36	3.2	12g	36	Pan	\$41.32	No	434	Both
M50	4.5	15g	50	Pan	\$44.72	No	740	Flat

value

Instance /Item

## Document

In the beginning God created the heaven and the earth. And the earth was without form, and void; and darkness was upon the face of the deep. And the Spirit of God moved upon the face of the waters. And God said, Let there be light: and there was light.

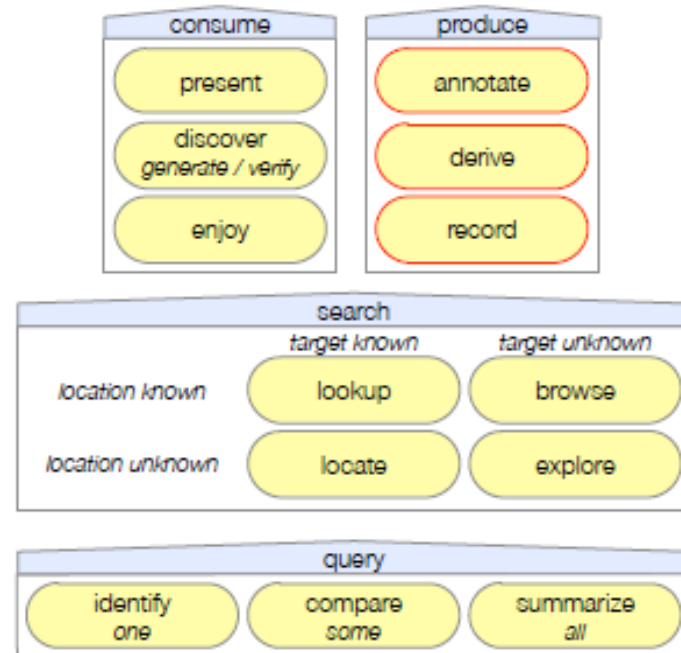
## Representation

beginning	1
earth	2
God	3

# WHY the user wants to visualize the data

## Goal/tasks

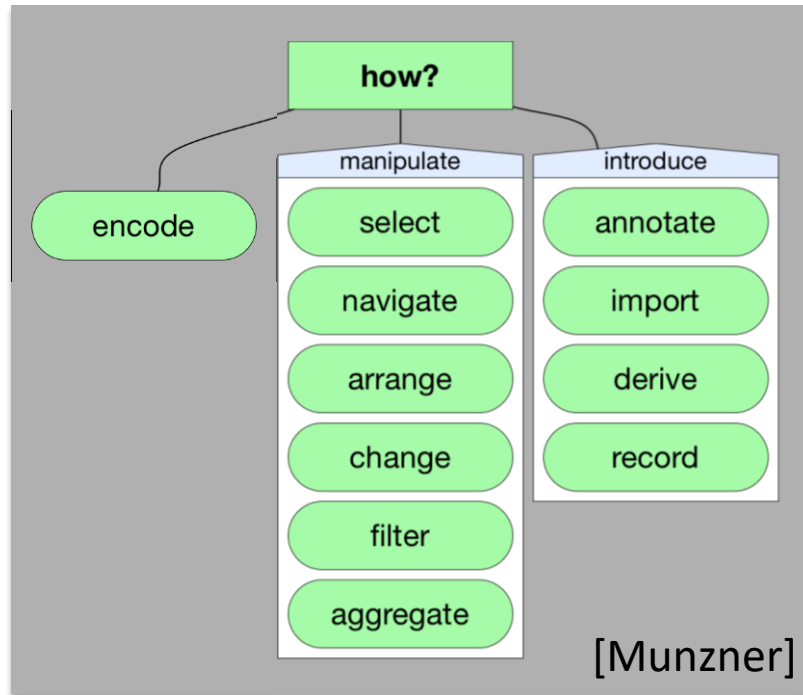
- Count
- Compare
- Classify
- Cluster
- Detect outliers
- Detect trend
- Find target
- Overview
- ...



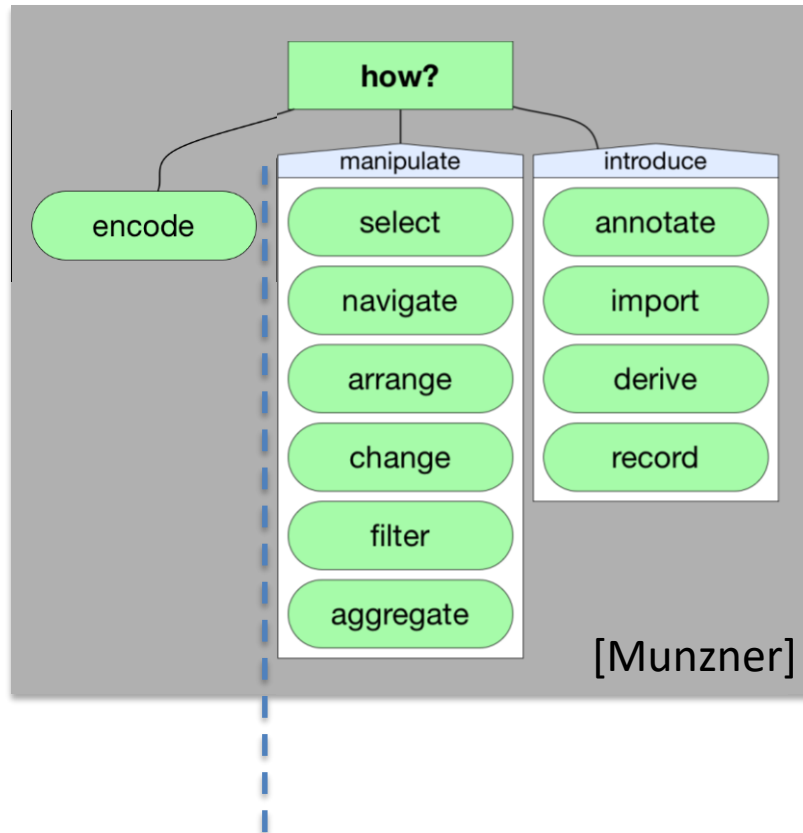
[Munzner]



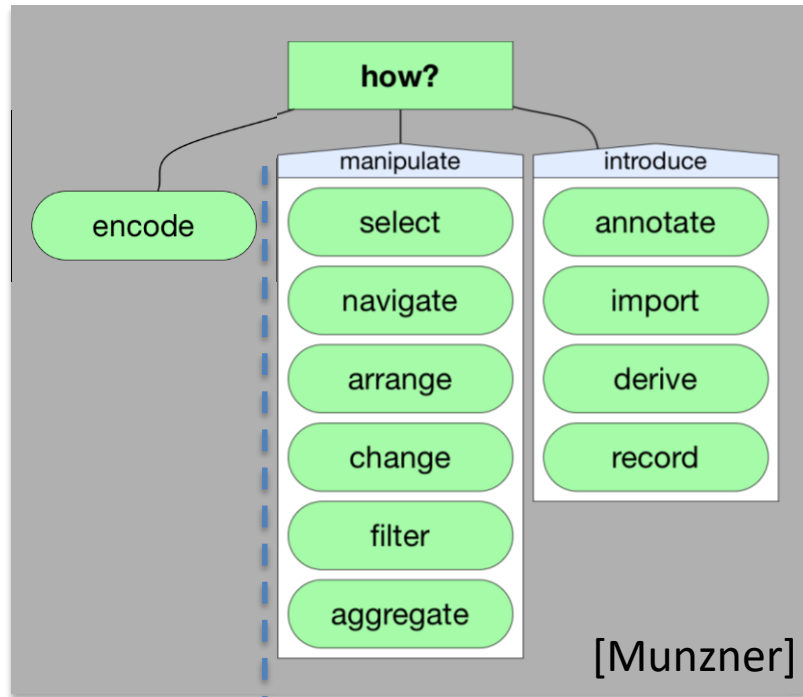
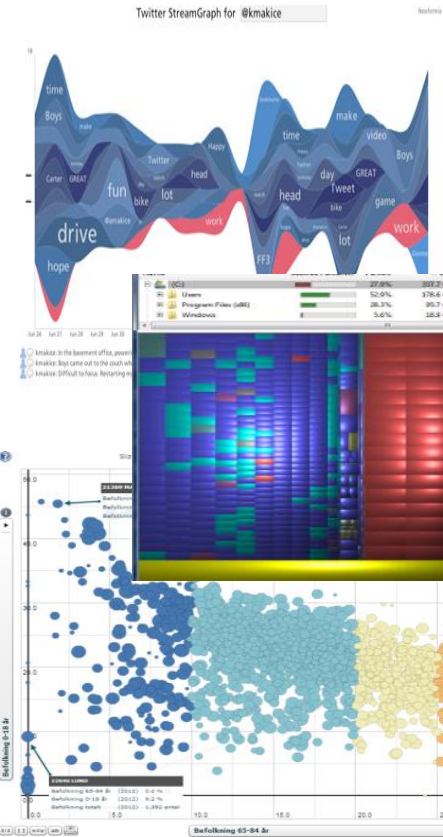
# HOW to visualize the data



# HOW to visualize the data



# HOW to visualize the data

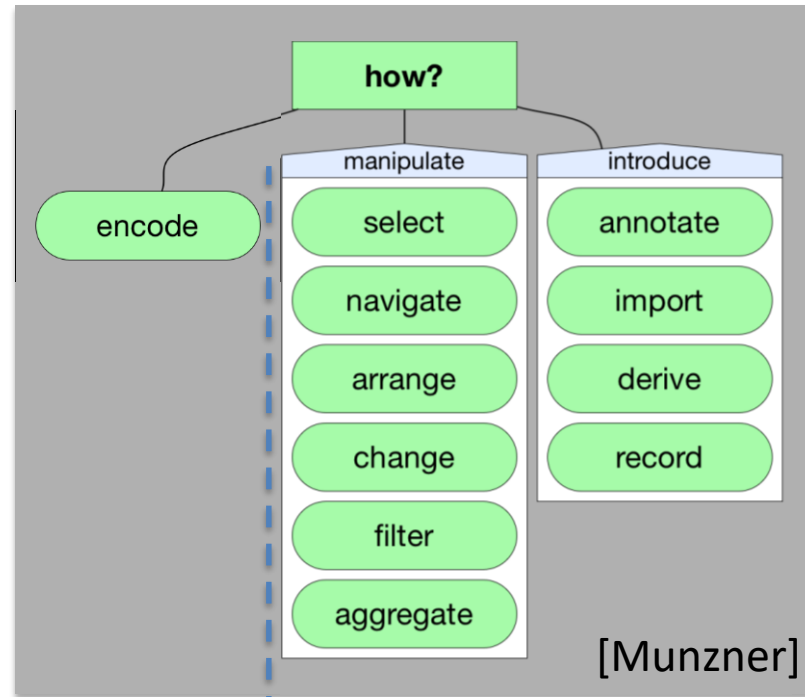
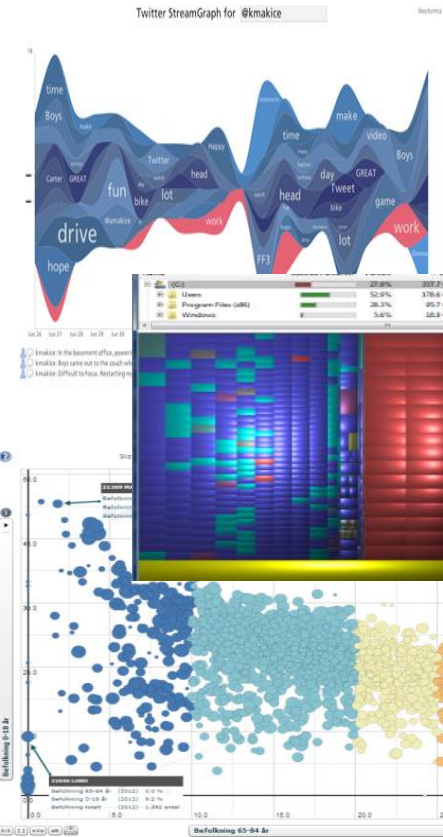


Visual idioms





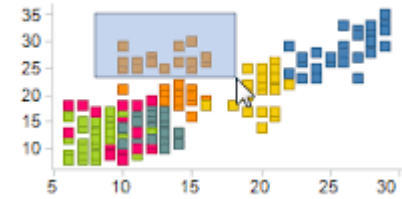
# HOW to visualize the data



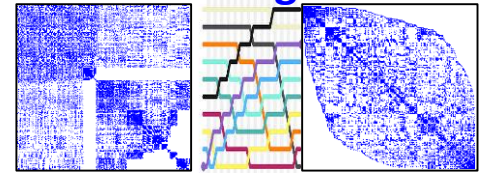
Visual idioms

Visual interactions

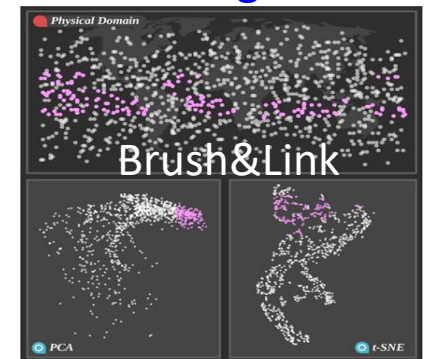
Select



Arrange



Change



# Visualization is still an Art

# Visualization is still an Art

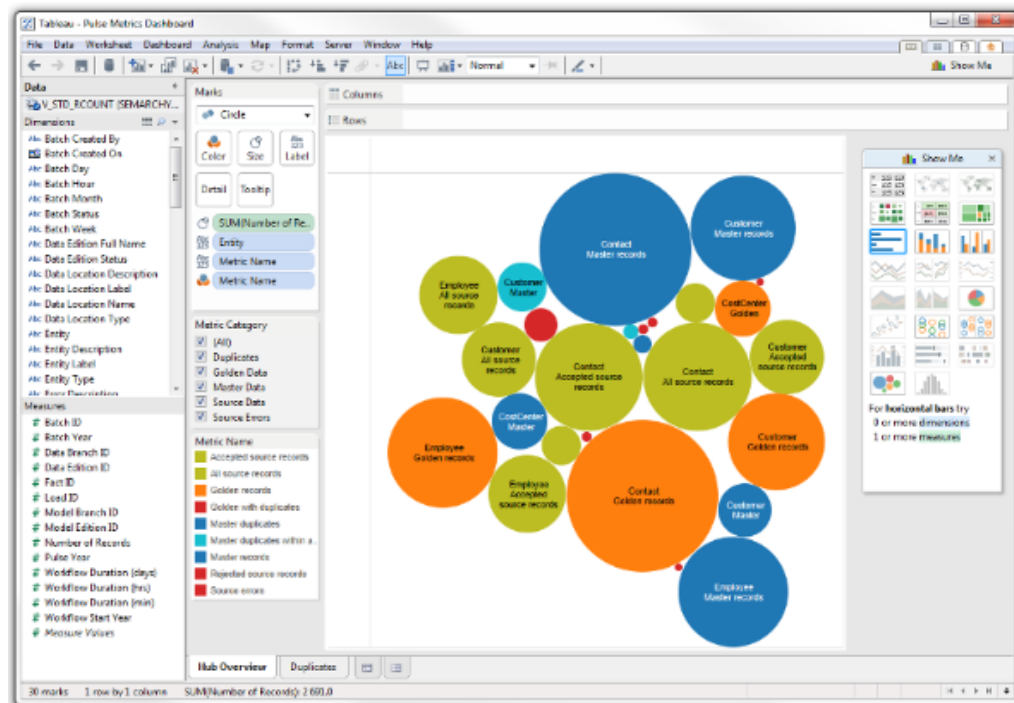
- There is no systematic/automatic way to get the **HOW** given the **WHO**, the **WHAT** and the **WHY**
- Some tools (*e.g.*, *Tableau*) give guidance to choose the visual idiom (**HOW**) given the data type (**WHAT**)

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# Visualization is still an Art

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- Some tools (e.g., *Tableau*) give guidance to choose the visual idiom (**HOW**) given the data type (**WHAT**)



# Outline

- What is Data Visualization?
- User Centered Design
- **Visual Perception**
- Criteria for Good Visualizations
- Some examples
- Resources

# Data Visualization **basics**

## Data types

Many different  
types of data exist

## Visual encoding

Optimal visual cues exist  
for each data type

## Analytic tasks

Some visual metaphors  
are more suited  
to some analytic tasks

# Data types

Many different  
types of variables exist



CONTINUOUS

$\neq$   $=$

$<$   $>$

$-$   $+$

$\times$   $\div$

## Data types

Many different  
types of variables exist

e.g. Air temperature



### CONTINUOUS

$\neq$   $=$

$<$   $>$

$-$   $+$

$\times$   $\div$

### COUNTABLE

$\neq$   $=$

$<$   $>$

$-$   $+$

## Data types

Many different  
types of variables exist

e.g. Air temperature



e.g. #Cars on  
the street



### CONTINUOUS

$\neq$   $=$

$<$   $>$

$-$   $+$

$\times$   $\div$

### COUNTABLE

$\neq$   $=$

$<$   $>$

$-$   $+$

### ORDERED

$\neq$   $=$

$<$   $>$

## Data types

Many different  
types of variables exist

e.g. Air temperature



e.g. #Cars on  
the street



e.g. Medal



**CONTINUOUS**

$\neq$   $=$   
 $<$   $>$   
 $-$   $+$   
 $\times$   $\div$

**COUNTABLE**

$\neq$   $=$   
 $<$   $>$   
 $-$   $+$

**ORDERED**

$\neq$   $=$   
 $<$   $>$

**CATEGORICAL**

$\neq$   $=$

e.g. Air temperature



e.g. #Cars on the street



e.g. Medal



e.g. Names/Things



# Data types

Many different types of variables exist

**CONTINUOUS**

$\neq$   $=$   
 $<$   $>$   
 $-$   $+$   
 $\times$   $\div$

e.g. Air temperature



**COUNTABLE**

$\neq$   $=$   
 $<$   $>$   
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e.g. #Cars on the street



**ORDERED**

$\neq$   $=$   
 $<$   $>$

e.g. Medal



**CATEGORICAL**

$\neq$   $=$

e.g. Names/Things



**CYCLIC**



# Data types

Many different types of variables exist

**CONTINUOUS**

$\neq$   $=$   
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e.g. Air temperature



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e.g. #Cars on the street



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# Data types

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**CONTINUOUS**

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e.g. Air temperature



**COUNTABLE**

$\neq$   $=$   
 $<$   $>$   
 $-$   $+$

e.g. #Cars on the street



**ORDERED**

$\neq$   $=$   
 $<$   $>$

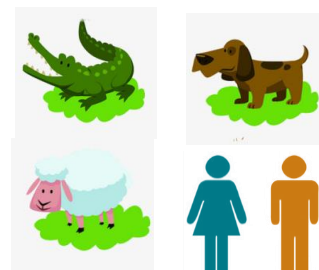
e.g. Medal



**CATEGORICAL**

$\neq$   $=$

e.g. Names/Things



**CYCLIC**





# ORDERED ATTRIBUTES

MOST EFFECTIVE

Channels: Expressiveness Types and Effectiveness Rank

## ➔ 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)

LEAST EFFECTIVE

# Visual encoding

Optimal visual cues exist for each data type



# ORDERED ATTRIBUTES


MOST EFFECTIVE

# CATEGORICAL ATTRIBUTES

Channels: Expressiveness Types and Effectiveness Rank

## ➔ 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  Same

Color saturation  Same

Curvature  Same

Volume (3D size)  Same

## ➔ Identity Channels: Categorical Attributes

Spatial region 

Color hue 

Motion 

Shape 



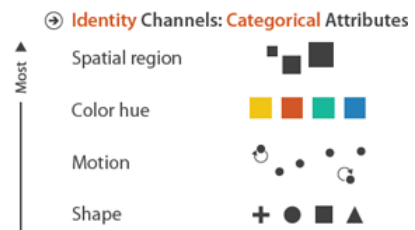
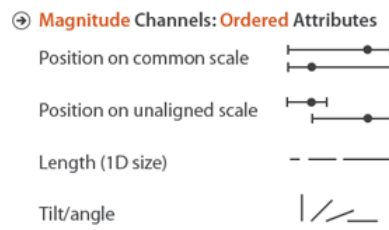
Tamara Munzner

# Visual encoding

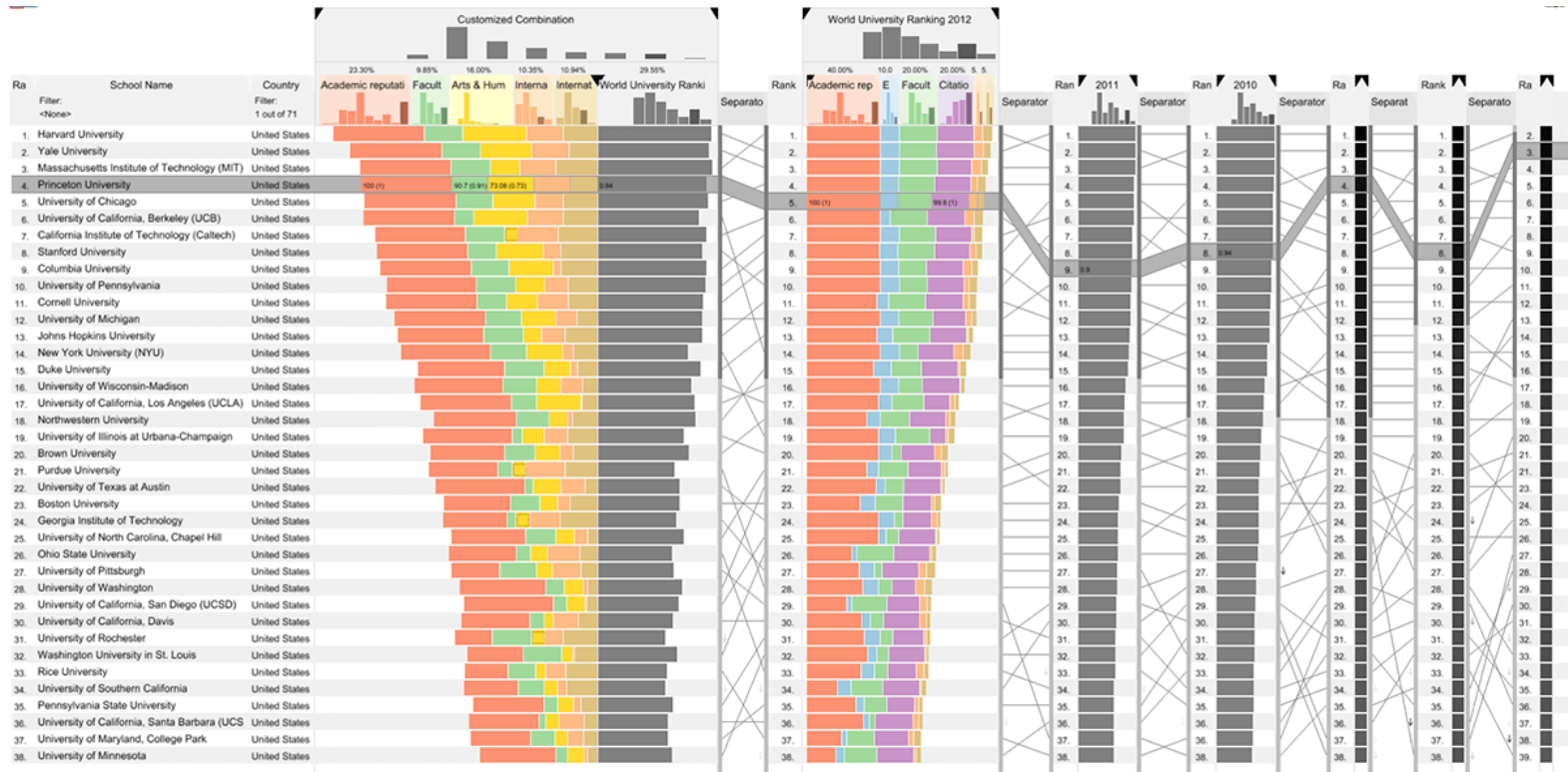
Optimal visual cues exist for each data type

LEAST EFFECTIVE

# LineUp



[https://caleydo.org/publications/2013\\_infovis\\_lineup/](https://caleydo.org/publications/2013_infovis_lineup/)



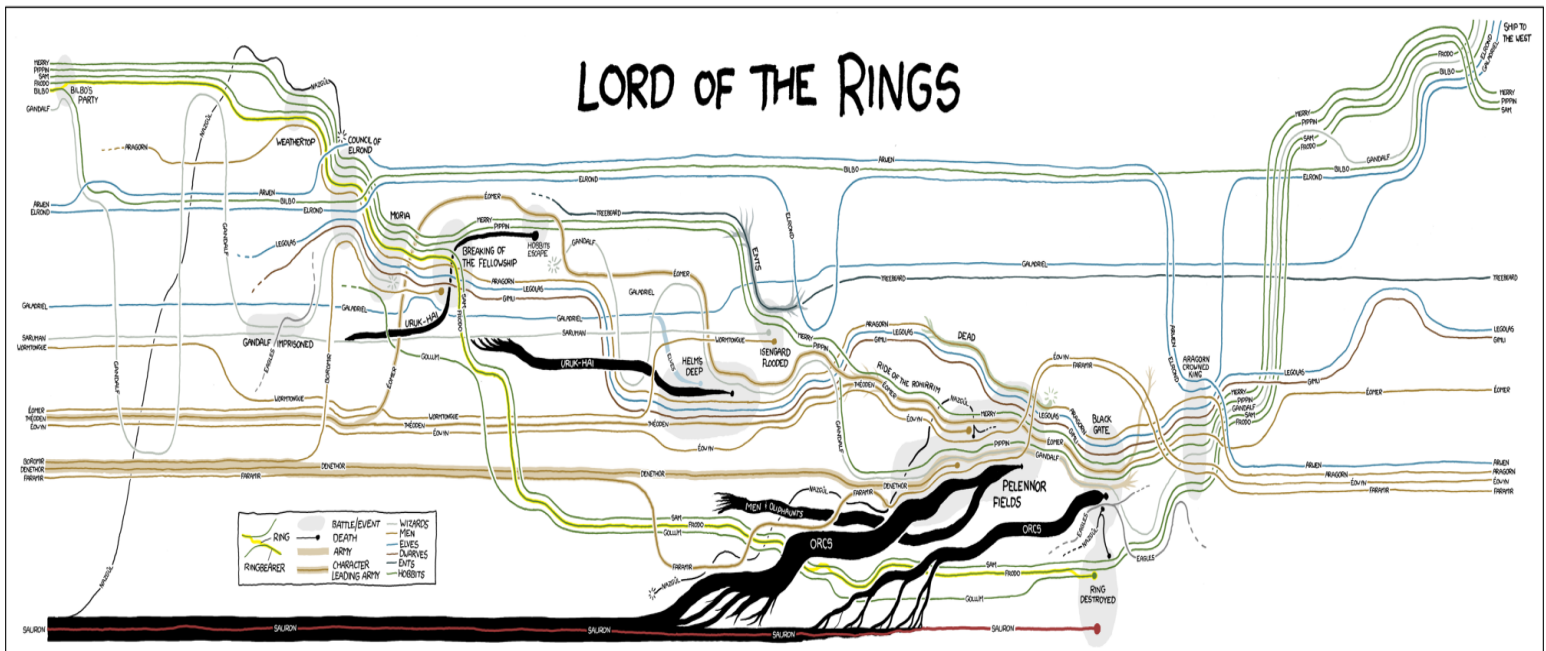
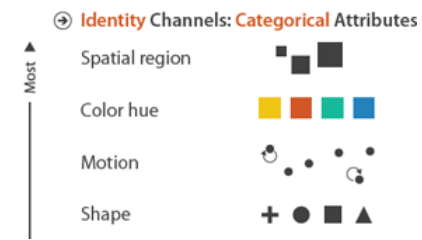
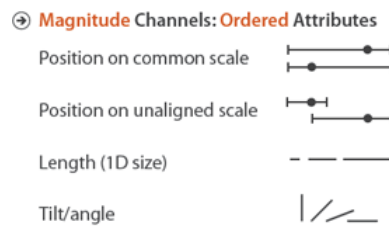
# Time and space

- Story visualization

Line: character

THESE CHARTS SHOW MOVIE CHARACTER INTERACTIONS. THE HORIZONTAL AXIS IS TIME. THE VERTICAL GROUPING OF THE LINES INDICATES WHICH CHARACTERS ARE TOGETHER AT A GIVEN TIME.

Y-axis: proximity



# Time and space

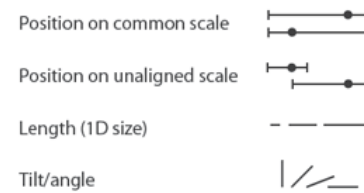
- Document editing

Line: paragraph  
Hue: author

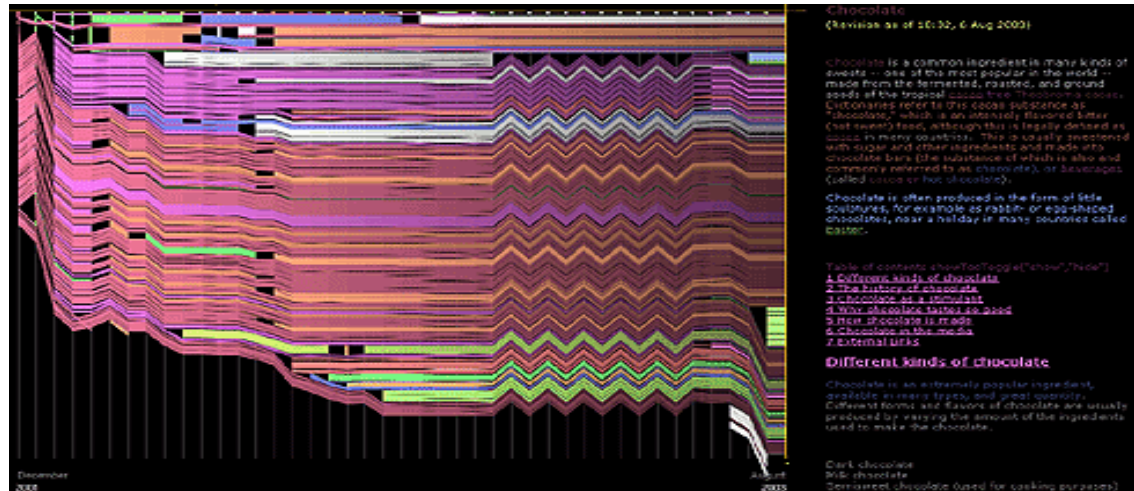
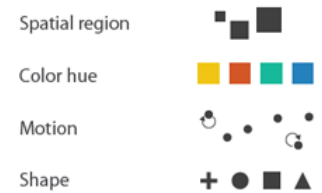
Y-axis:  
Order in  
document

X-axis: time

## ➤ Magnitude Channels: Ordered Attributes



## ➤ Identity Channels: Categorical Attributes



# Time and space

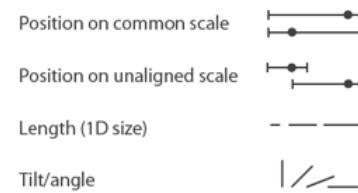
- Document editing

Line: paragraph  
Hue: author

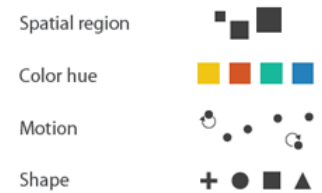
Y-axis:  
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# Time and space

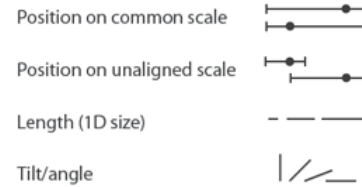
- Document editing

Line: paragraph  
Hue: author

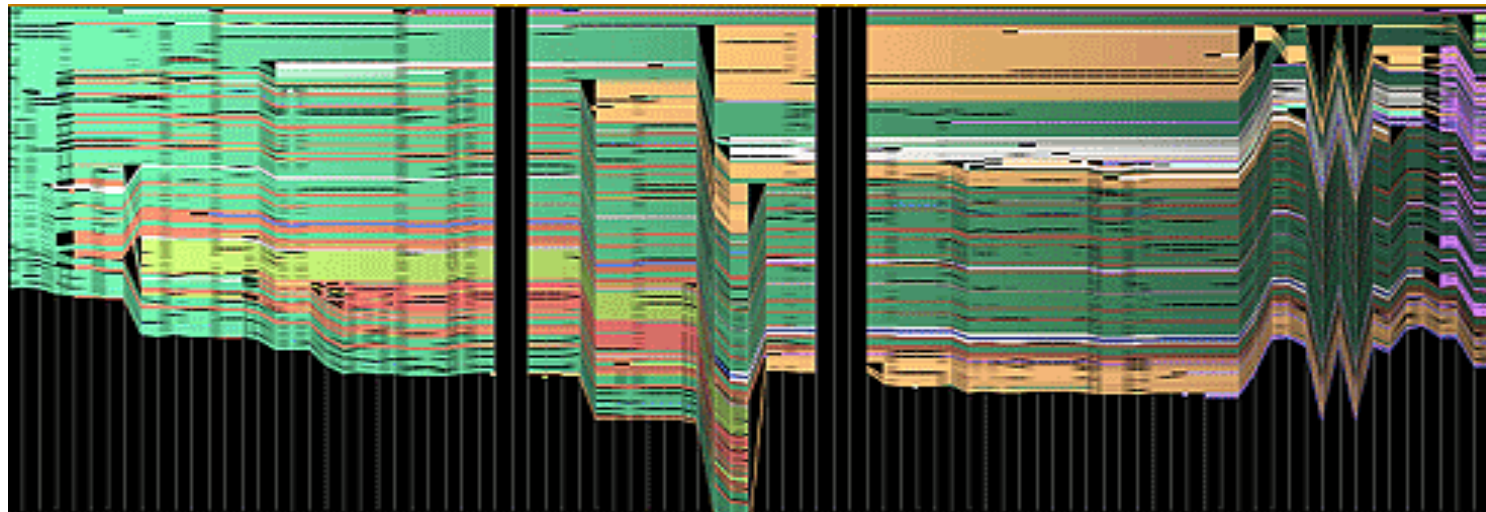
Y-axis:  
Order in  
document

X-axis: time

## Magnitude Channels: Ordered Attributes



## Identity Channels: Categorical Attributes



# Time and space

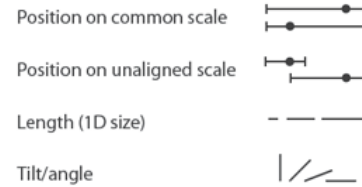
- Document editing

Line: paragraph  
Hue: author

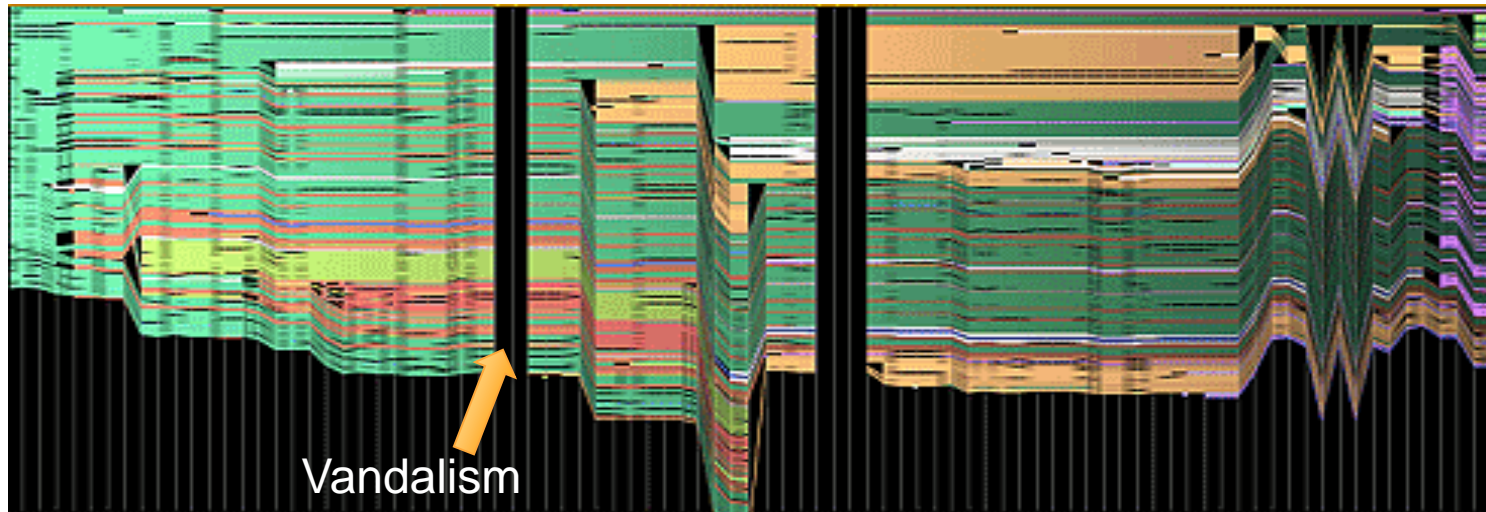
Y-axis:  
Order in document

X-axis: time

## Magnitude Channels: Ordered Attributes

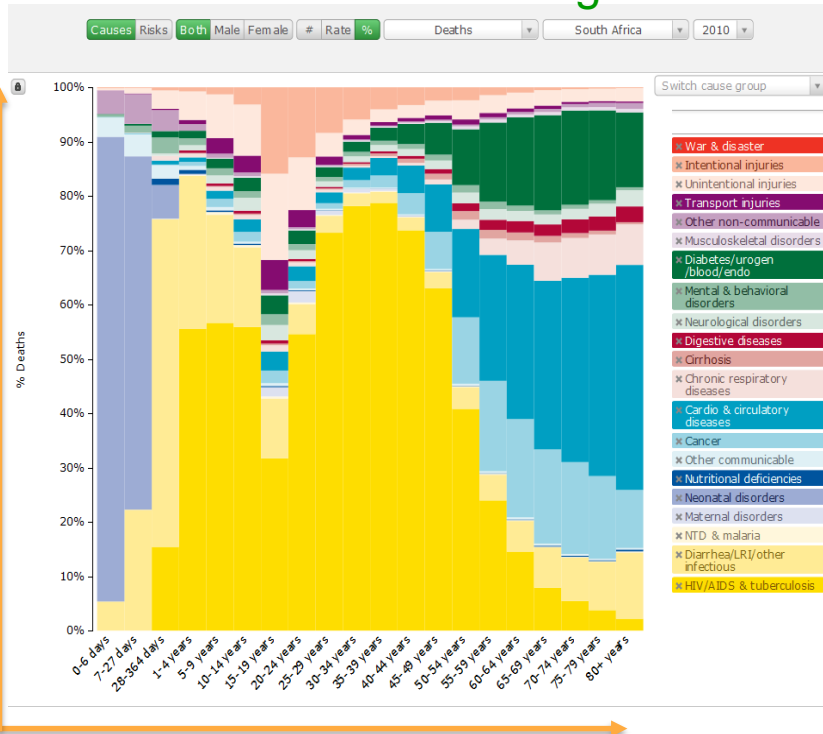


## Identity Channels: Categorical Attributes



# Time and space

Hue: cause of death category  
 Saturation: subcategories



- **Magnitude Channels: Ordered Attributes**
- Position on common scale:
  - Position on unaligned scale:
  - Length (1D size):
  - Tilt/angle:

- **Identity Channels: Categorical Attributes**
- Spatial region:
  - Color hue:
  - Motion:
  - Shape:

Proportion

Discrete time

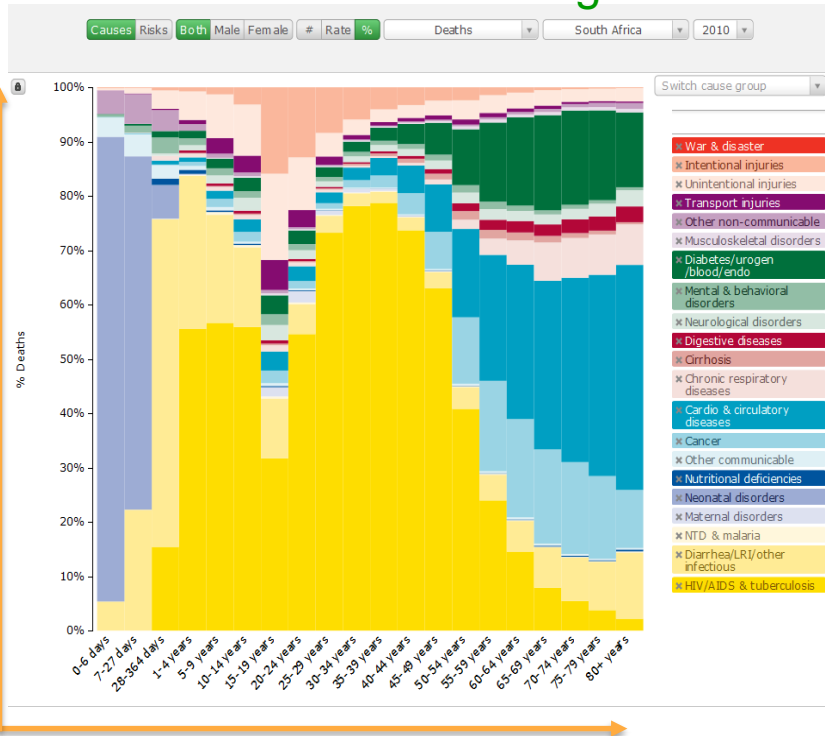


# Time and space

- ⊕ Magnitude Channels: Ordered Attributes
- Position on common scale
  - Position on unaligned scale
  - Length (1D size)
  - Tilt/angle

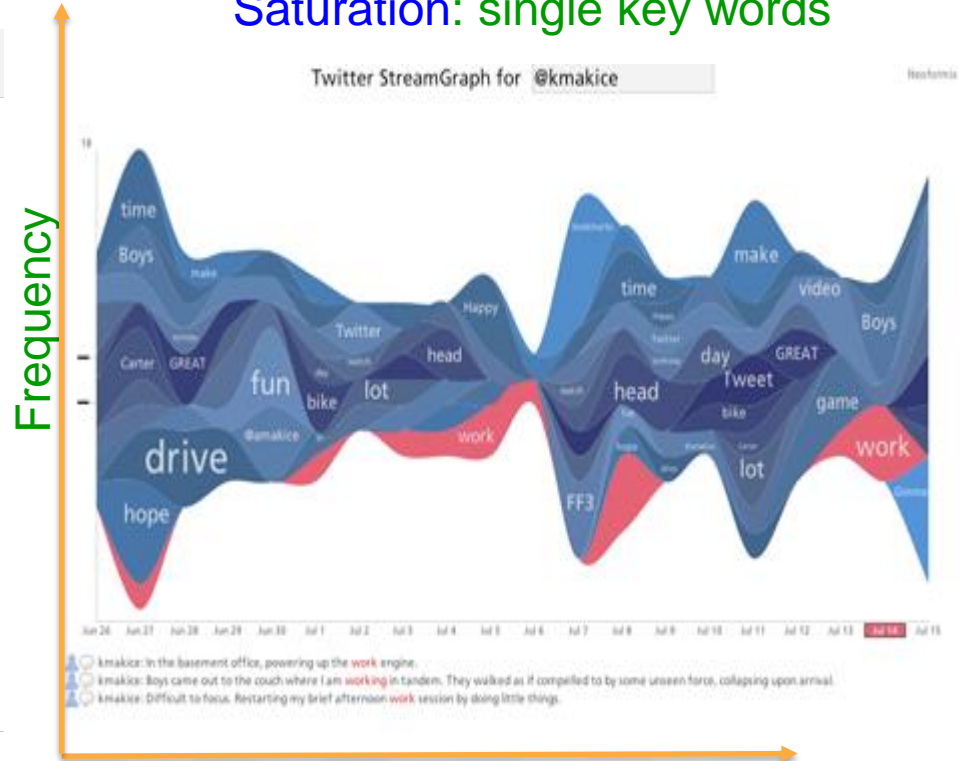
- ⊕ Identity Channels: Categorical Attributes
- Spatial region
  - Color hue
  - Motion
  - Shape

Hue: cause of death category  
Saturation: subcategories



Discrete time

Hue: key words category  
Saturation: single key words



Continuous time

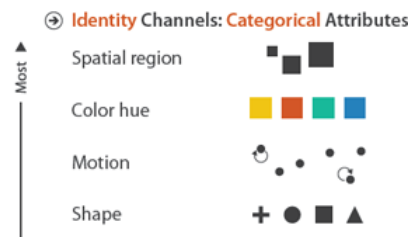
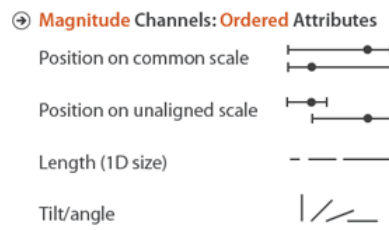
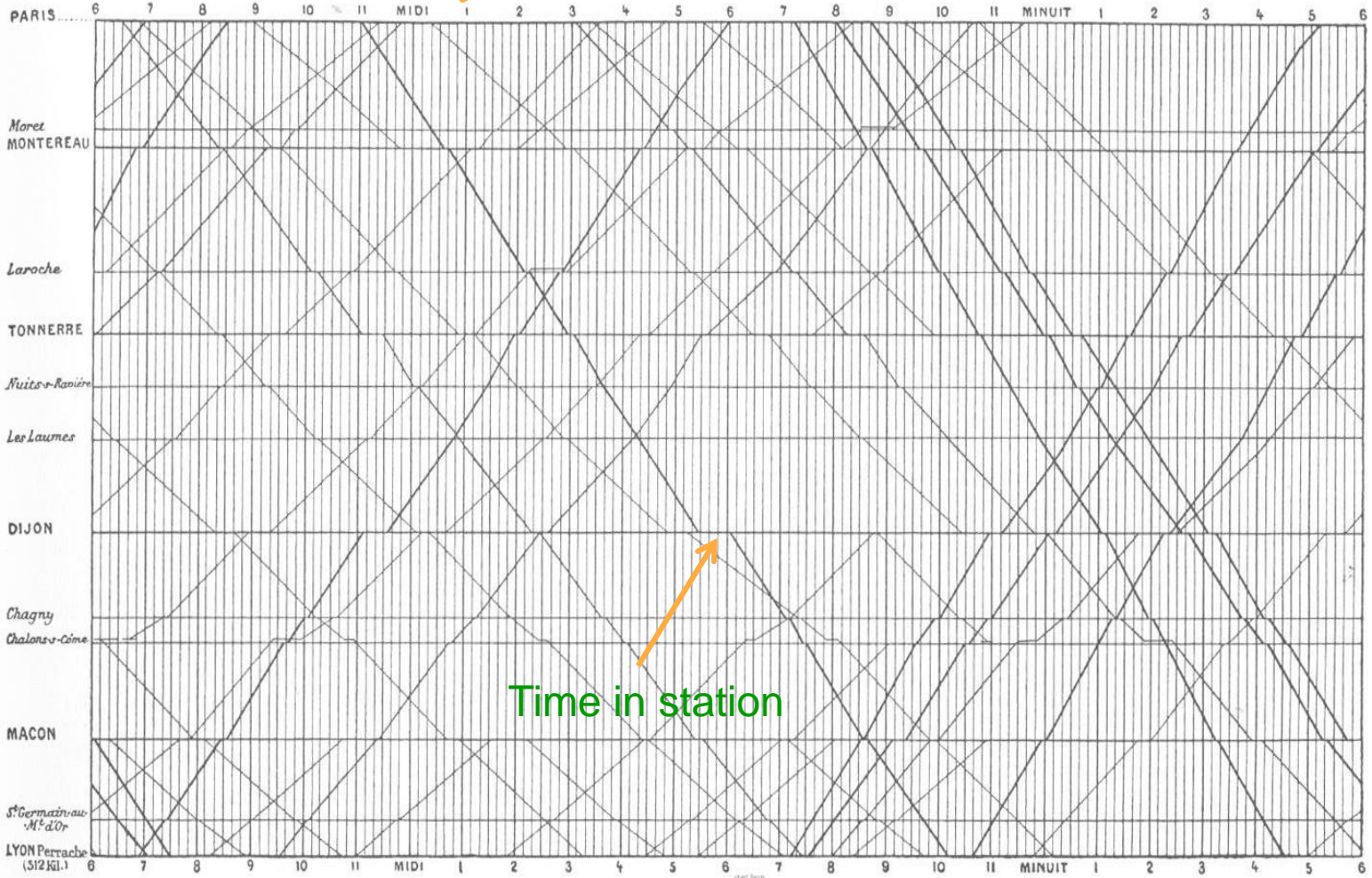
# Time and space

- Train schedule

Slope = Speed + Direction  
 Intervals = Frequency

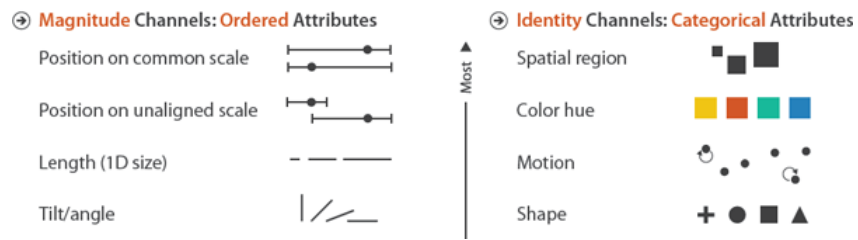
X-axis Time

Y-axis  
 Distance

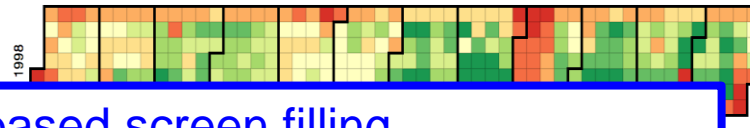
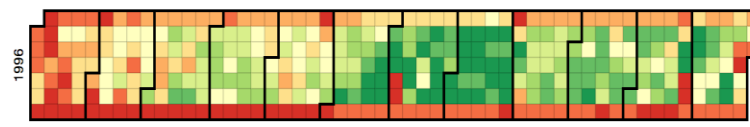
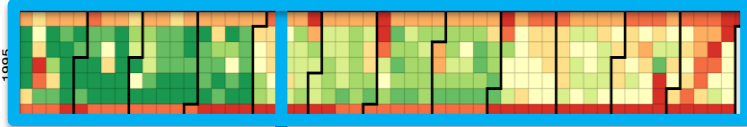


# Time and space

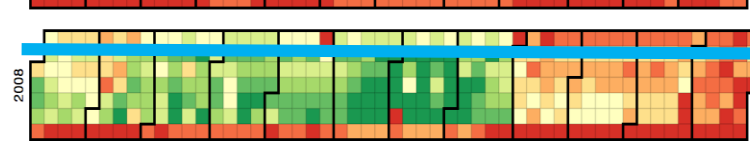
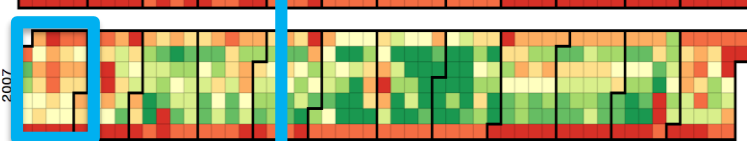
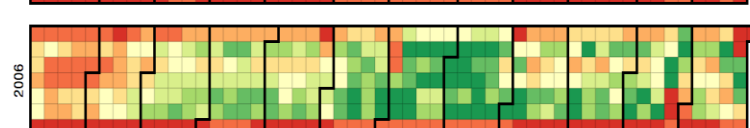
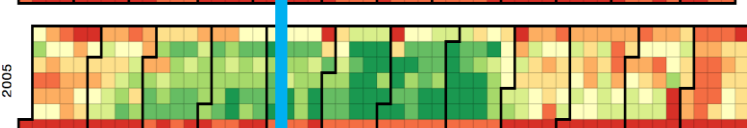
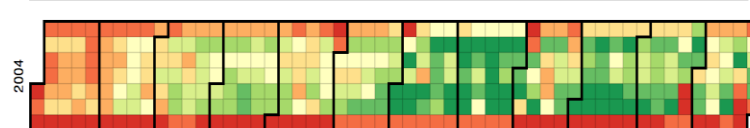
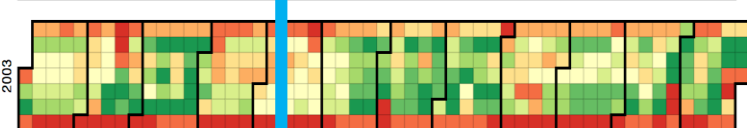
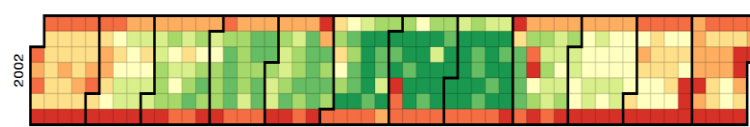
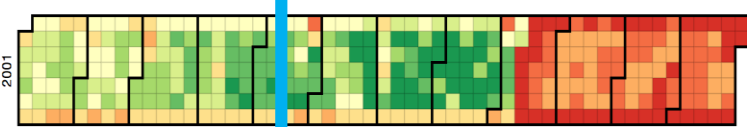
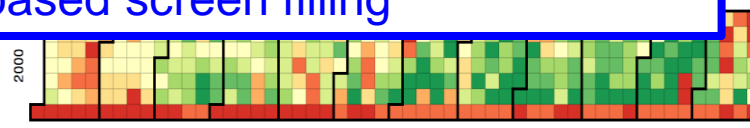
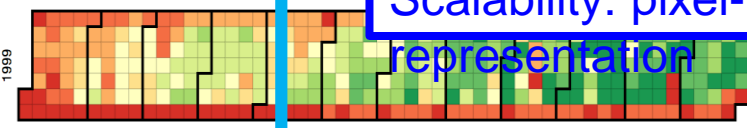
- Flights traffic heatmap calendar



1 year



Scalability: pixel-based screen filling representation



Same day

1 month

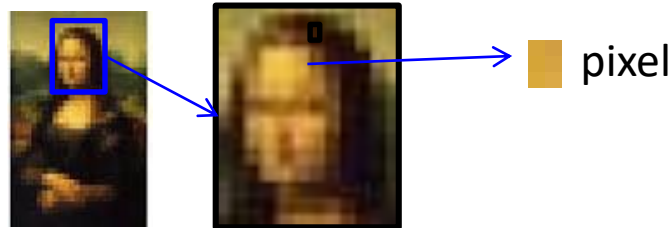
across years cycles across week days cycles, across week in month cycles, across months cycles

<http://mbostock.github.com/d3/talk/20111018/calendar.html>

# Visual Perception of colors

- Pixels

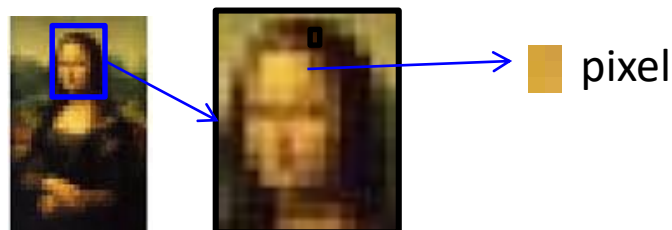
- They are the basic elements forming the image that encode the information to be analyzed by the human (user)



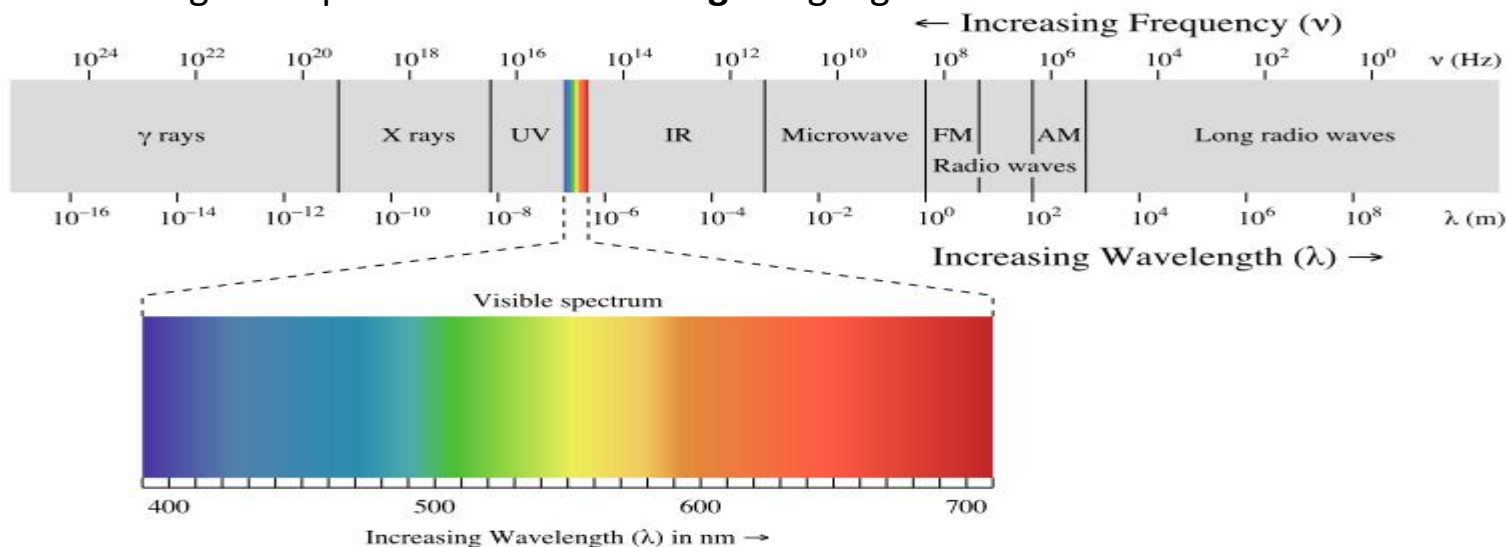
# Visual Perception of colors

- Pixels

- They are the basic elements forming the image that encode the information to be analyzed by the human (user)



Electromagnetic spectrum with **visible light** highlighted



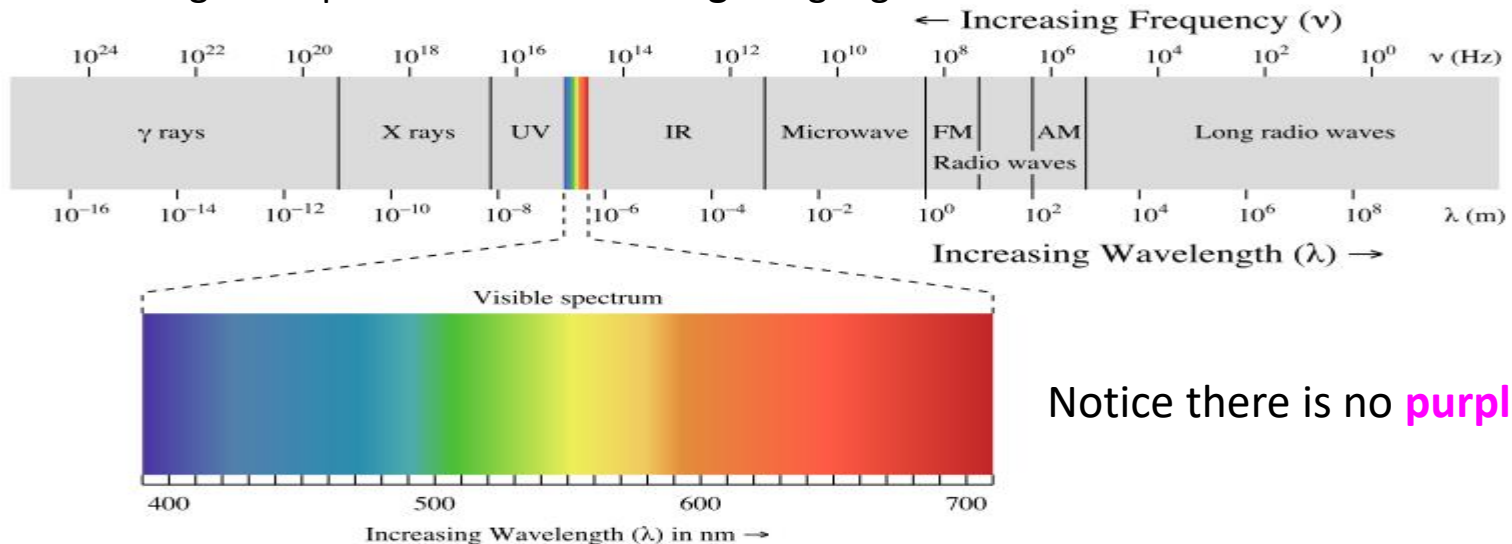
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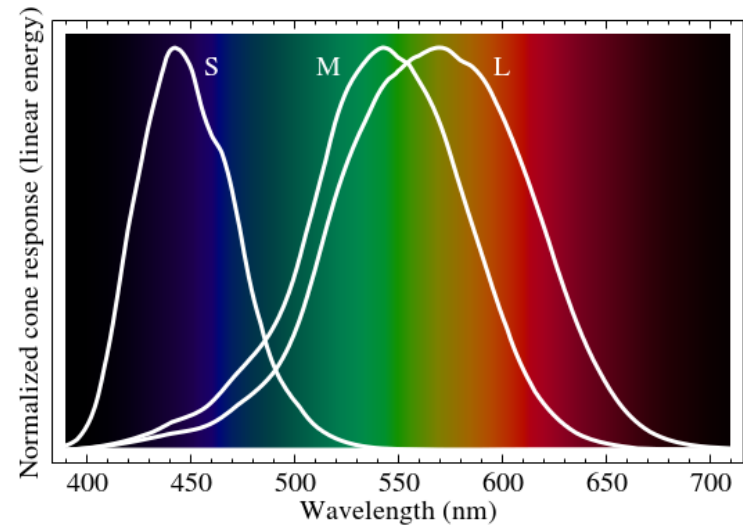
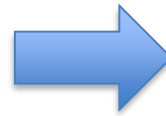
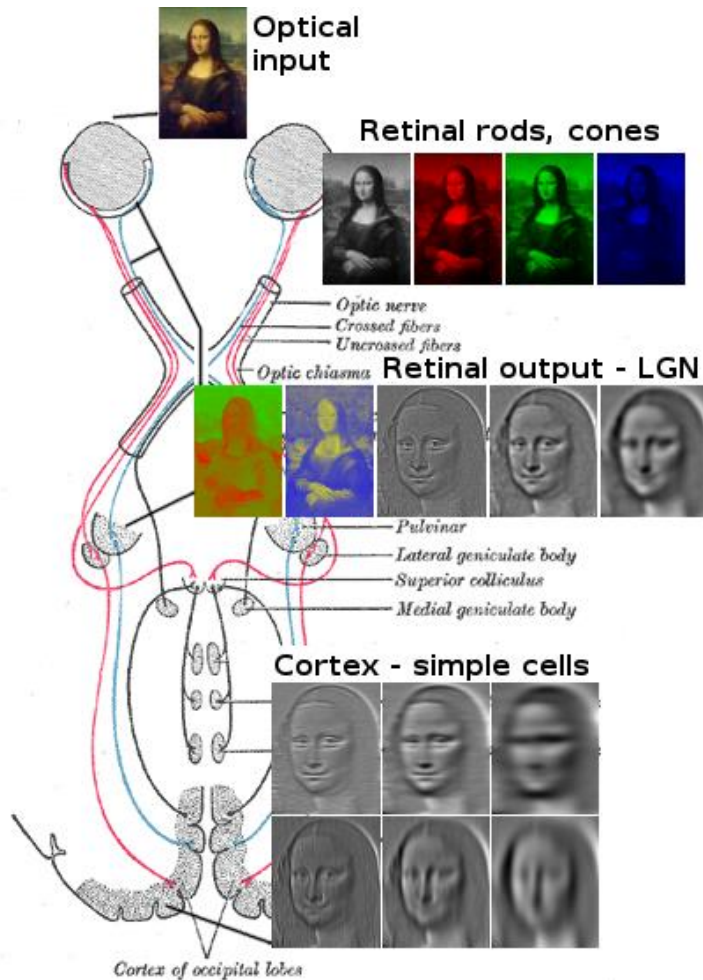


Notice there is no **purple** color here



# Visual Perception of colors

- Color is a **construction** of the visual perception system

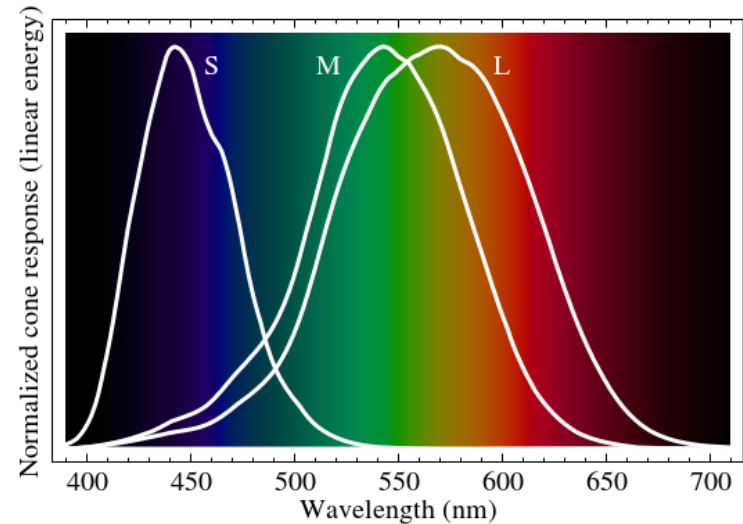
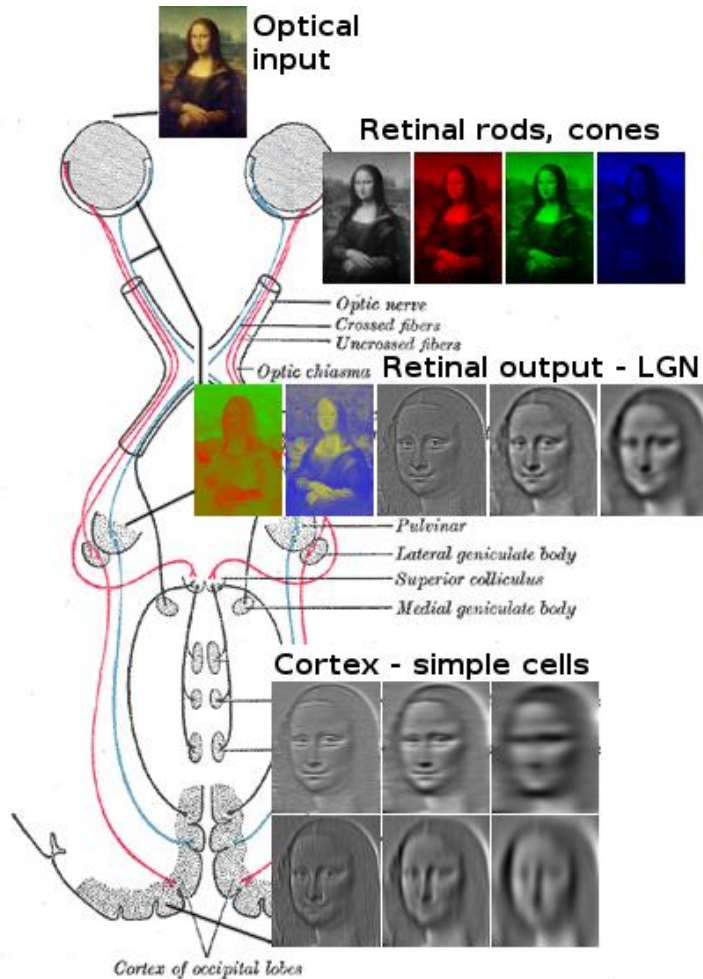


Normalized response spectra of human cones, S, M, and L types, to monochromatic spectral stimuli, with wavelength given in nanometers.



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- Color is a **construction** of the visual perception system



Normalized response spectra of human cones, S, M, and L types, to monochromatic spectral stimuli, with wavelength given in nanometers.

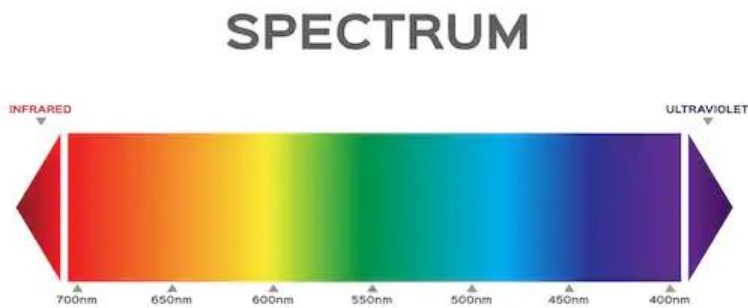
Notice there is no **purple** color here



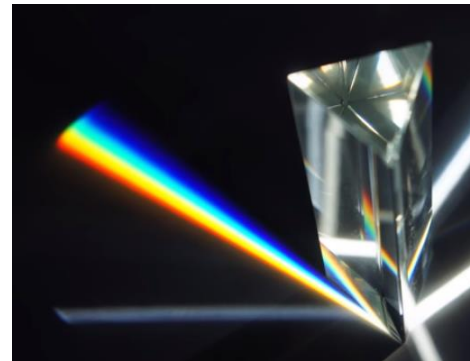


# There is no purple color???

- <https://www.youtube.com/watch?v=CoLQF3cfxv0>



shutterstock.com • 1011507874



# Visual Perception of colors

<https://www.youtube.com/watch?v=Qj1FK8n7WgY>

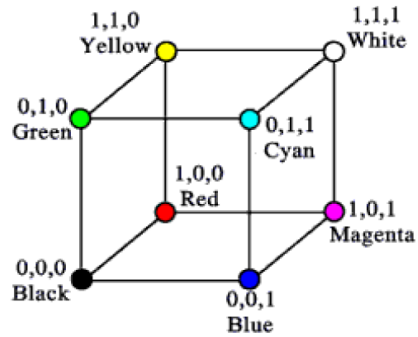
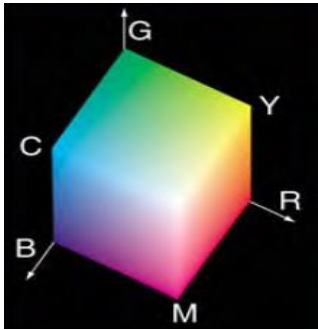
# Visual Perception of colors

- Color models
  - Red Green Blue (RGB) used by computer display
  - Hue Saturation Value (HSV) better to manage visual encoding/perception

<https://www.youtube.com/watch?v=Qj1FK8n7WgY>

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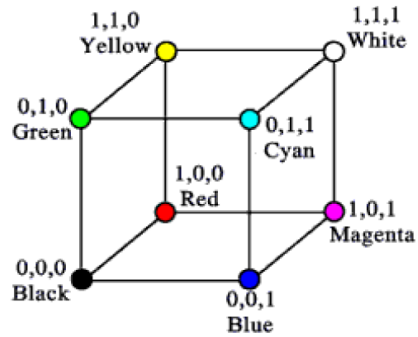
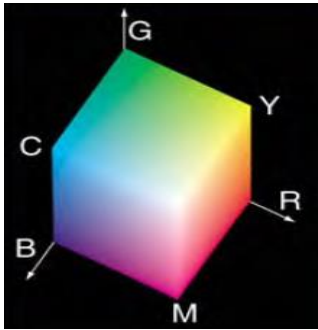
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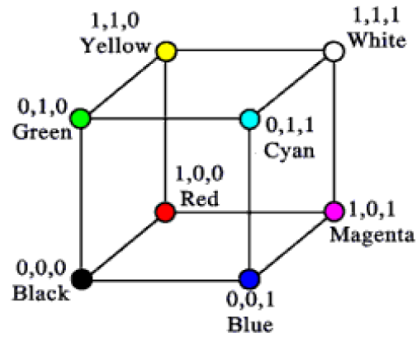
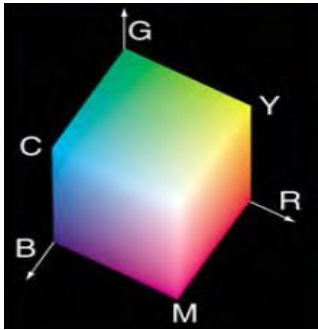
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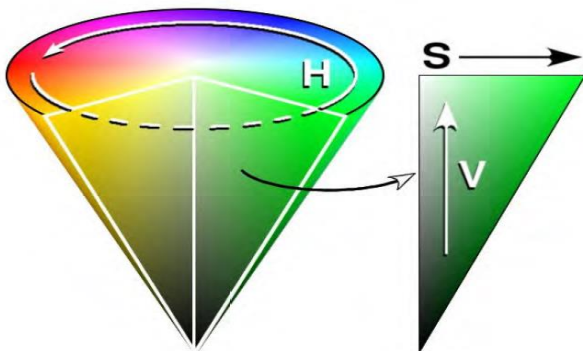
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- Red Green Blue (RGB) used by computer display



- Hue Saturation Value (HSV) better to manage visual encoding/perception



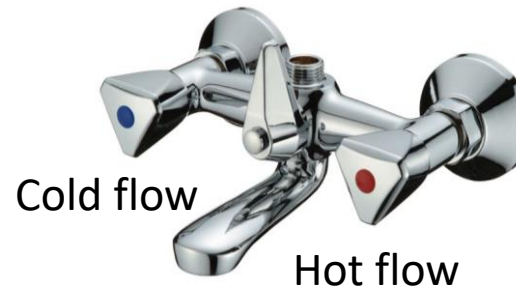
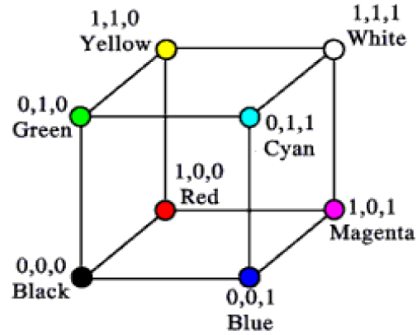
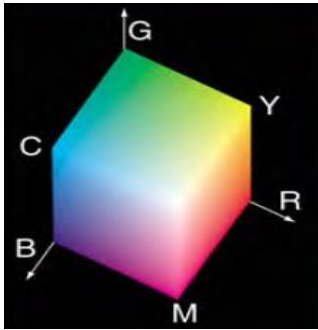
<https://www.youtube.com/watch?v=Qj1FK8n7WgY>



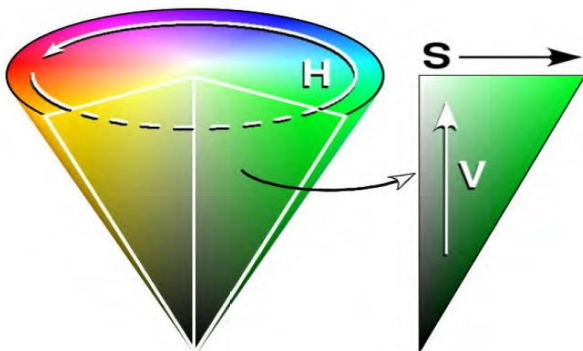
# Visual Perception of colors

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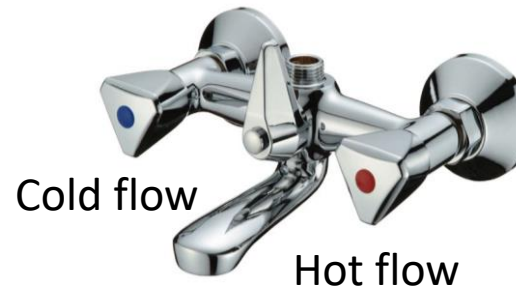
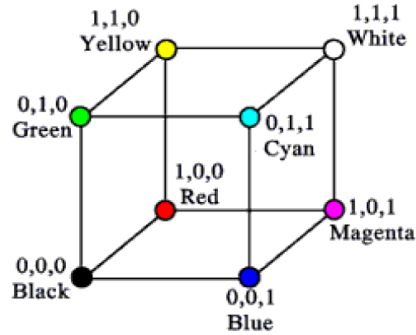
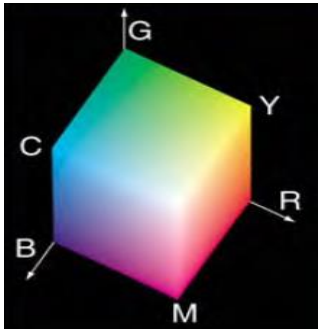


<https://www.youtube.com/watch?v=Qj1FK8n7WgY>

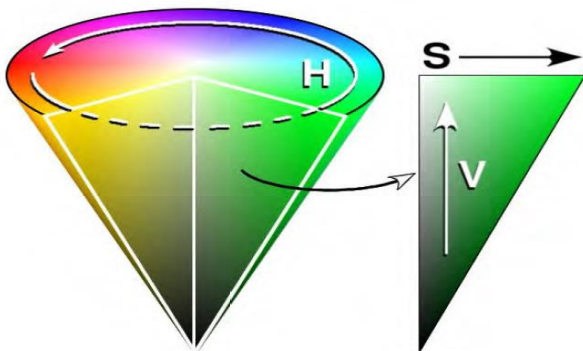
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<https://www.youtube.com/watch?v=Qj1FK8n7WgY>

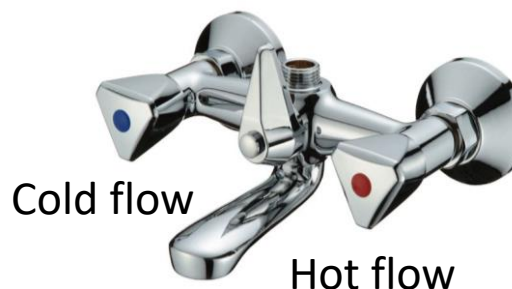
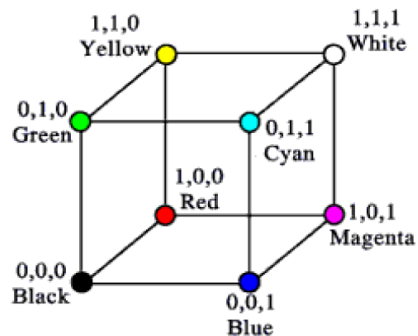
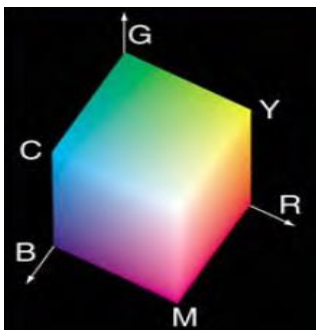




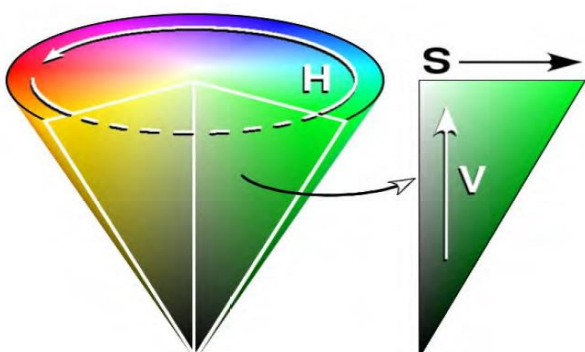
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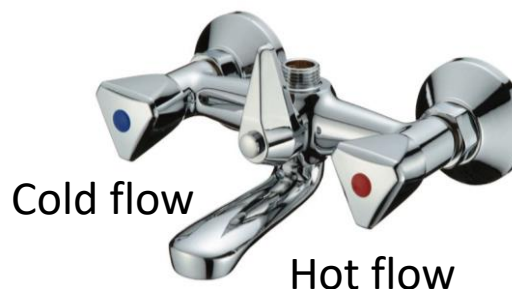
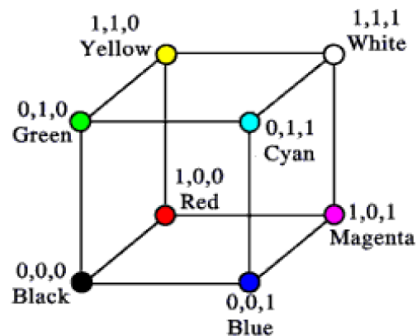
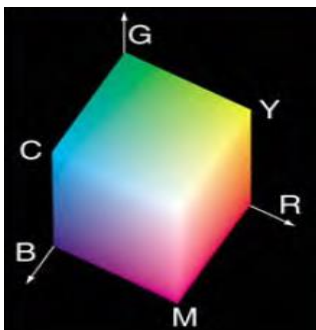
<https://www.youtube.com/watch?v=Qj1FK8n7WgY>



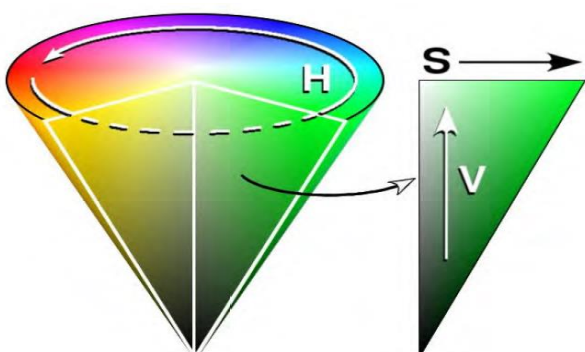
# Visual Perception of colors

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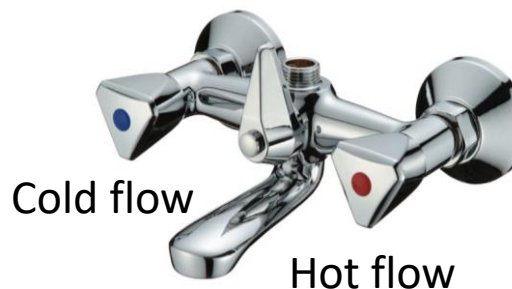
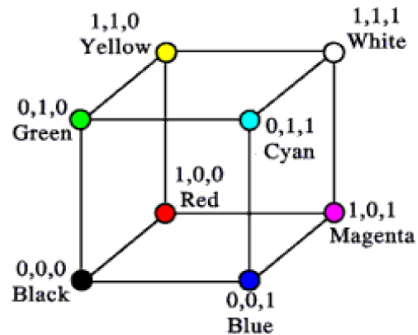
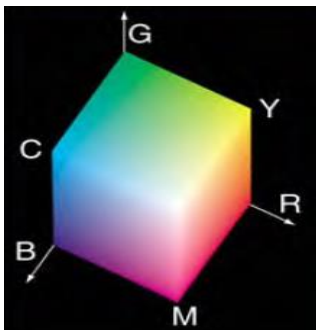
<https://www.youtube.com/watch?v=Qj1FK8n7WgY>



# Visual Perception of colors

- Color models

- Red Green Blue (RGB) used by computer display



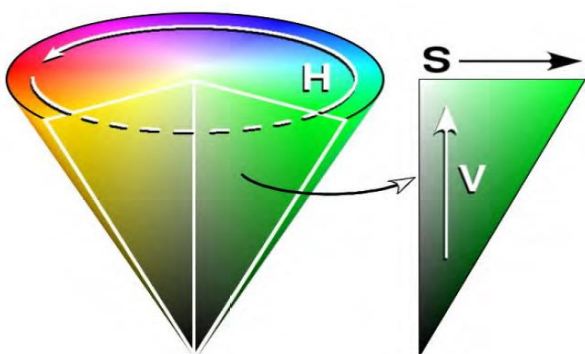
- Hue Saturation Value (HSV) better to manage visual encoding/perception

**No perceptual ordering of Hue**

temperature



flow

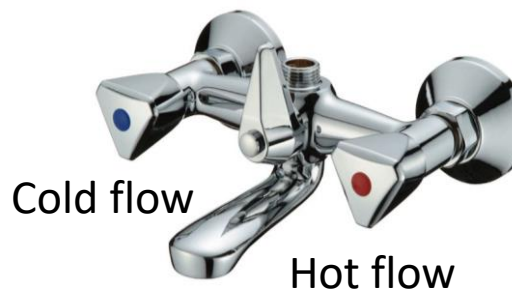
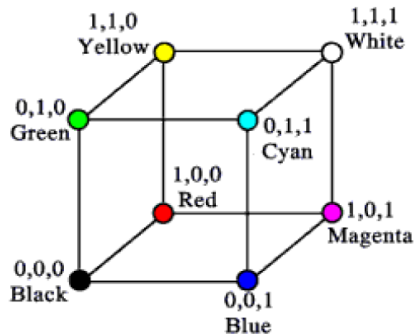
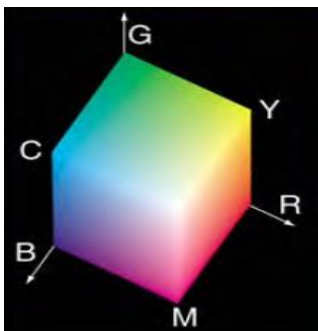


<https://www.youtube.com/watch?v=Qj1FK8n7WgY>

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temperature



**Hue better to encode nominal variables**

flow



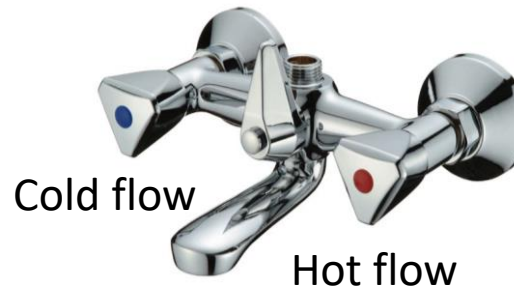
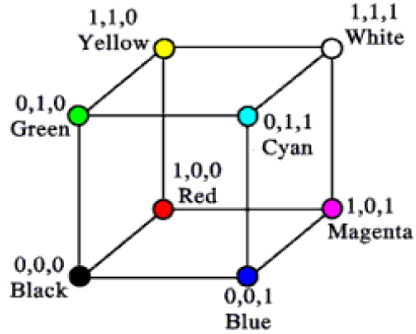
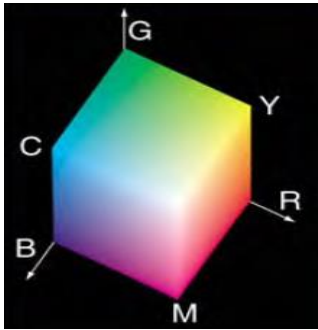
<https://www.youtube.com/watch?v=Qj1FK8n7WgY>



# Visual Perception of colors

- Color models

- Red Green Blue (RGB) used by computer display



- Hue Saturation Value (HSV) better to manage visual encoding/perception

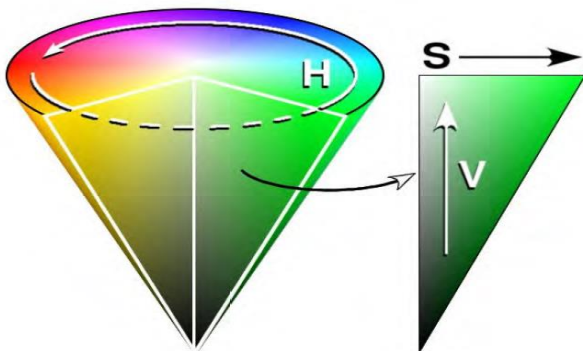
**No perceptual ordering of Hue**

temperature



**Hue better to encode nominal variables**

**Perceptual ordering of Value/Saturation**

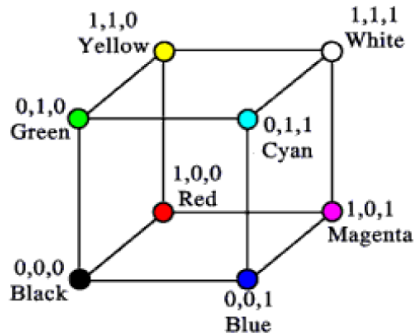
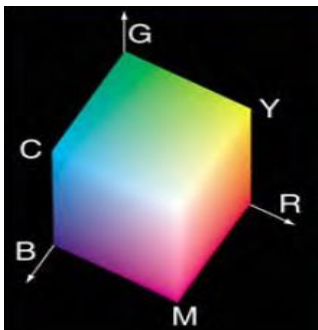


<https://www.youtube.com/watch?v=Qj1FK8n7WgY>

# Visual Perception of colors

- Color models

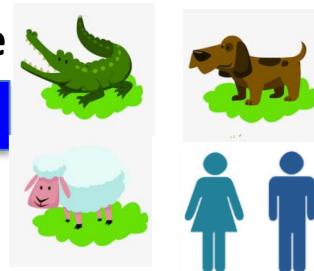
- Red Green Blue (RGB) used by computer display



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**No perceptual ordering of Hue**

temperature

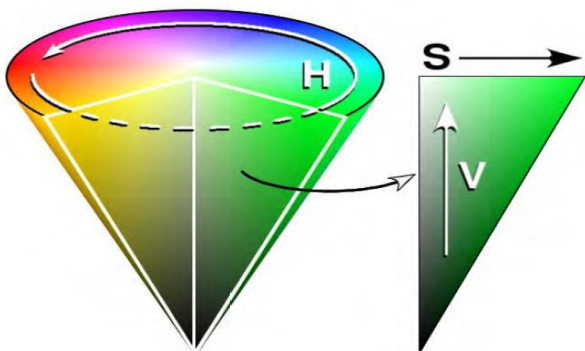


**Hue better to encode nominal variables**

**Perceptual ordering of Value/Saturation**



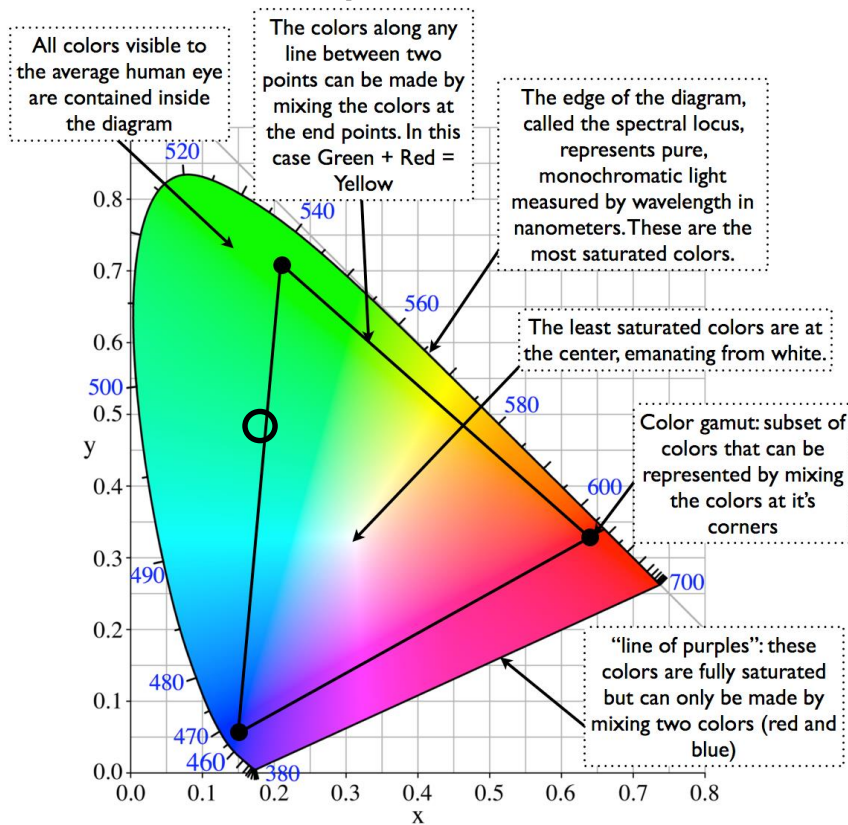
**Saturation and Value better to encode ordinal or quantitative variables**



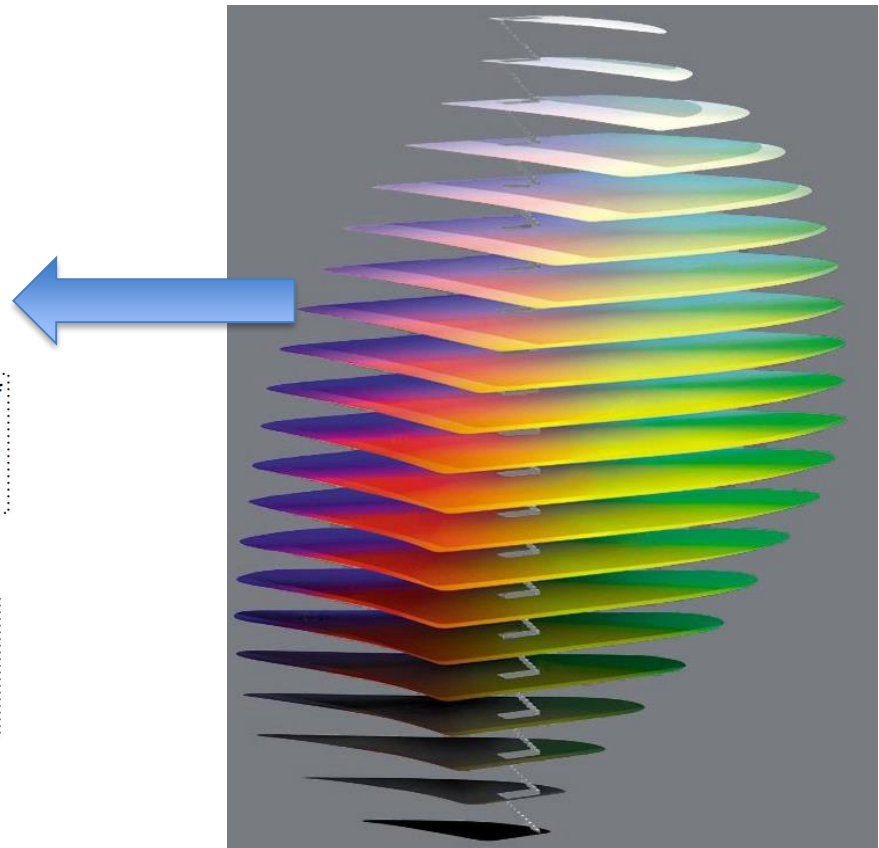
<https://www.youtube.com/watch?v=Qj1FK8n7WgY>

# Visual Perception of colors

- CIE lab: perceptually uniform color space
- Use this space for bidimensional color scales

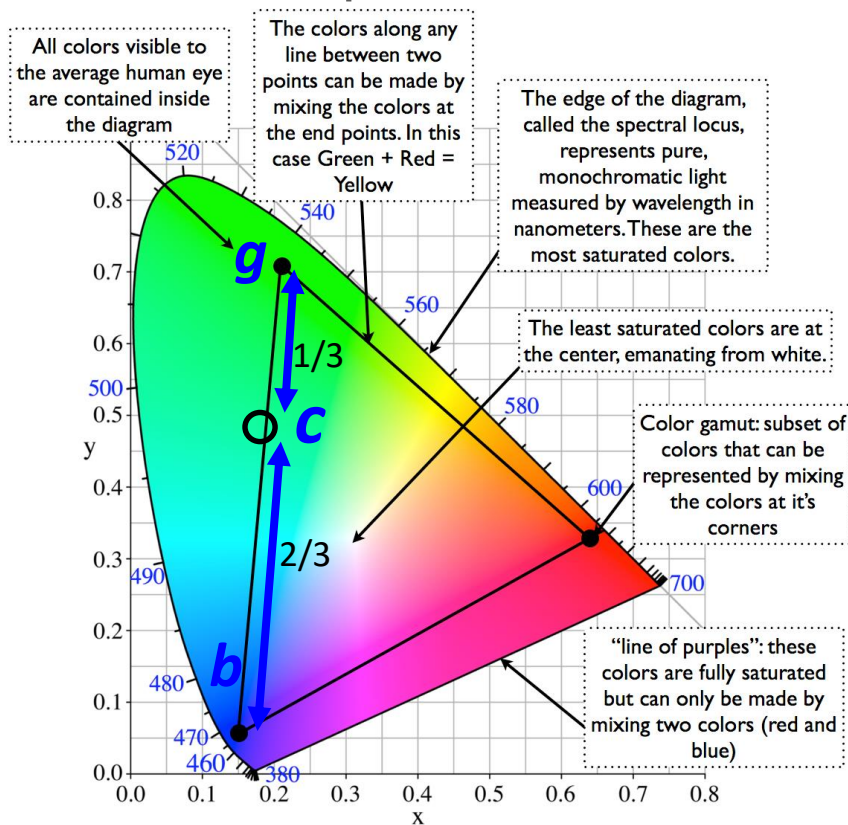


Anatomy of a CIE Chromaticity Diagram

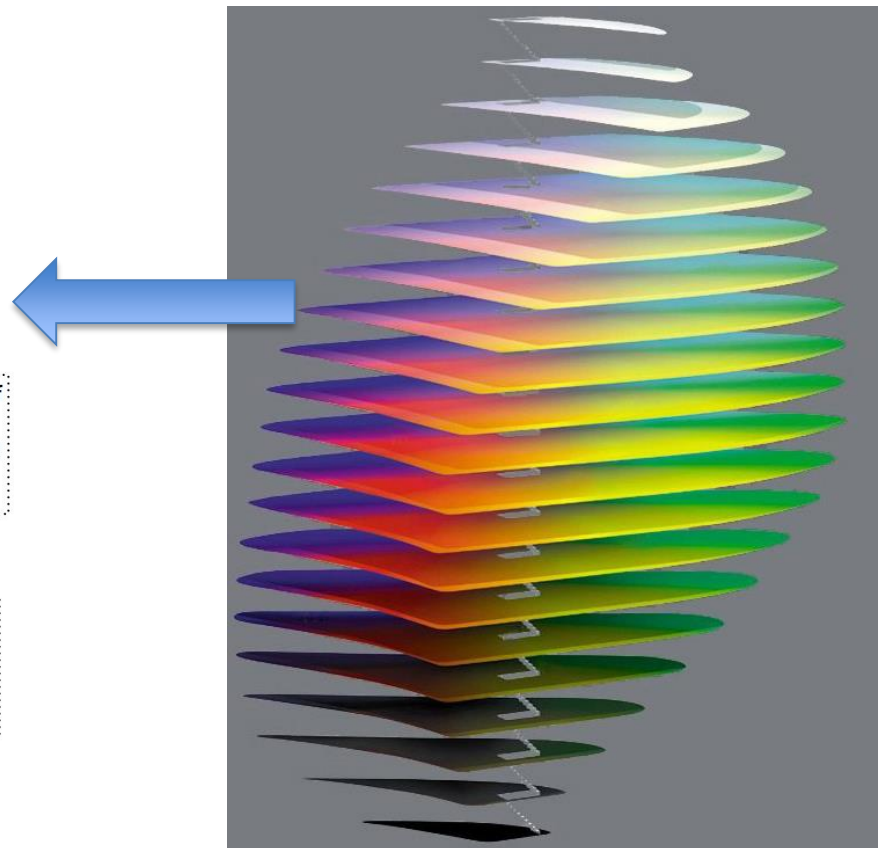


# Visual Perception of colors

- CIE lab: perceptually uniform color space
- Use this space for bidimensional color scales



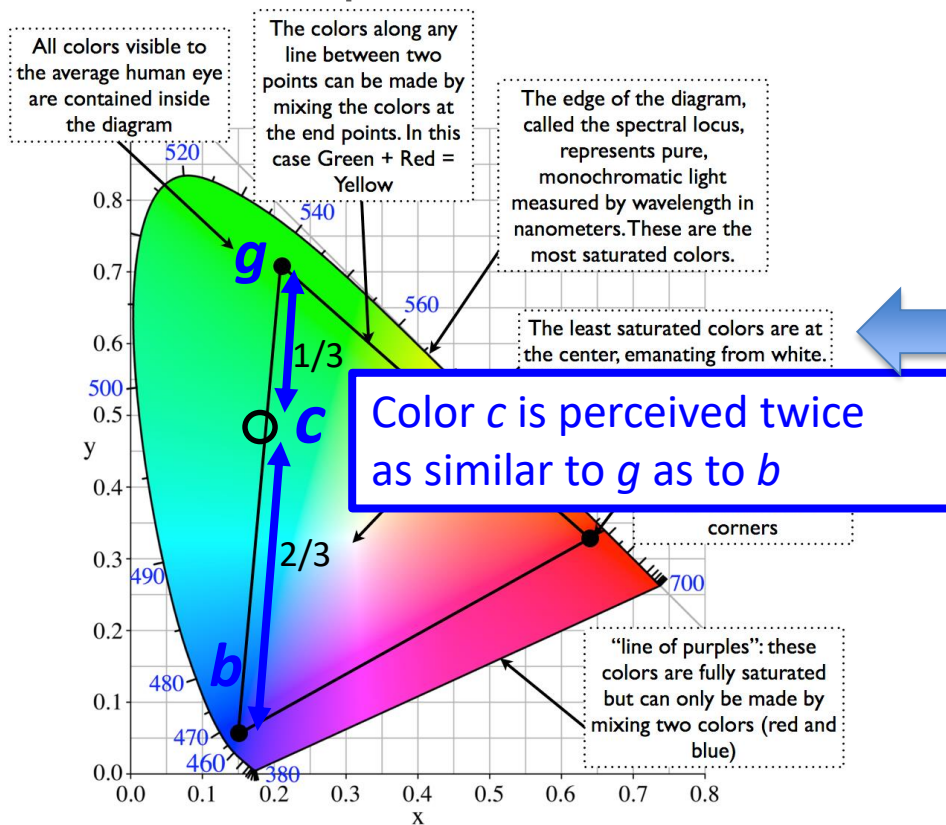
Anatomy of a CIE Chromaticity Diagram



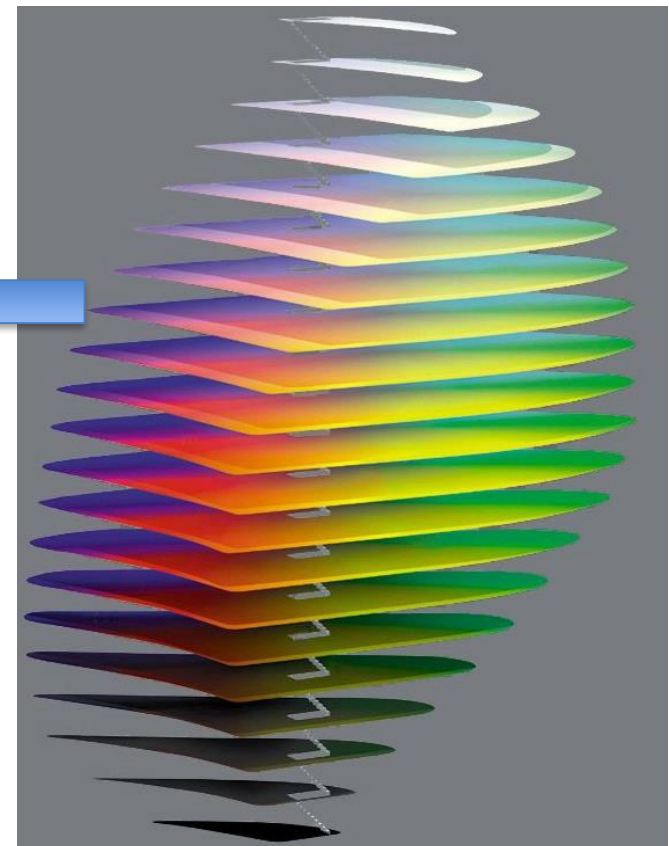


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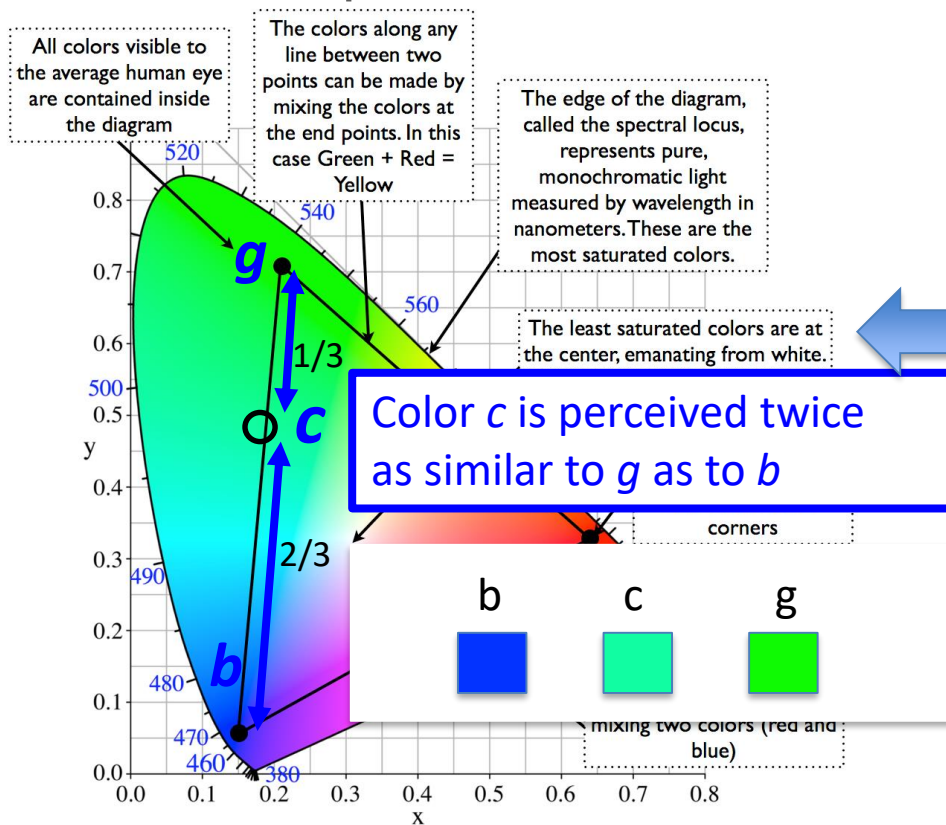


Anatomy of a CIE Chromaticity Diagram

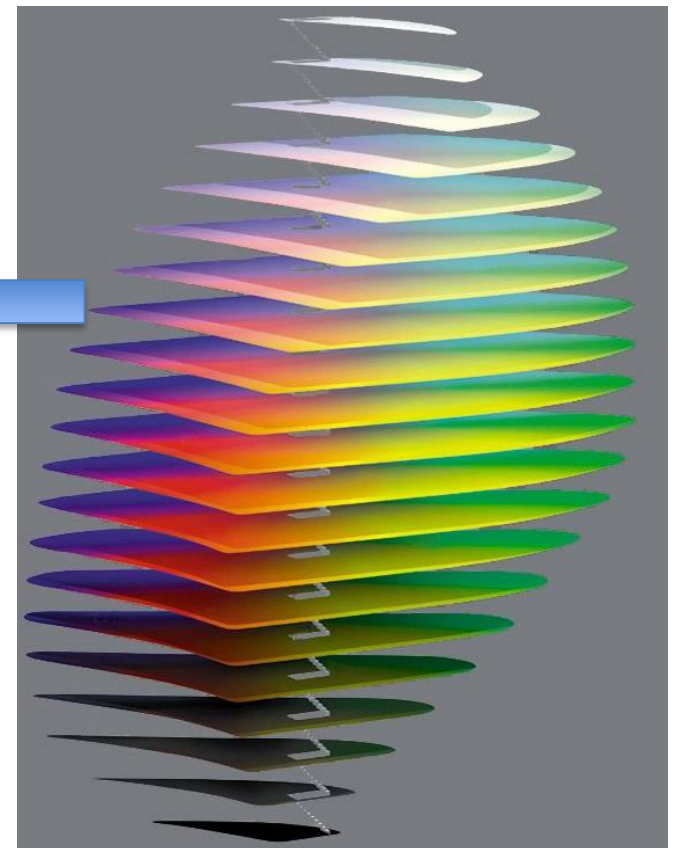


# Visual Perception of colors

- CIE lab: perceptually uniform color space
- Use this space for bidimensional color scales



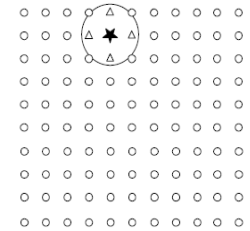
Anatomy of a CIE Chromaticity Diagram



# Example of bidimensional color scale

- Displaying distortions in Multi Dimensional Scaling

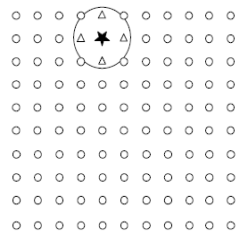
Original



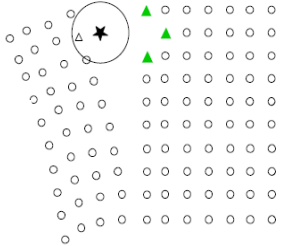
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- Displaying distortions in Multi Dimensional Scaling

Original



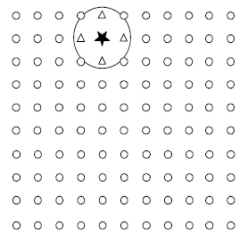
Miss



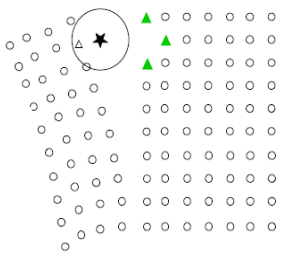
# Example of bidimensional color scale

- Displaying distortions in Multi Dimensional Scaling

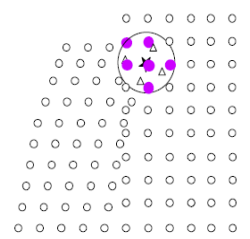
Original



Miss



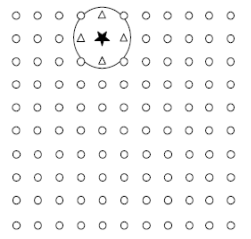
False



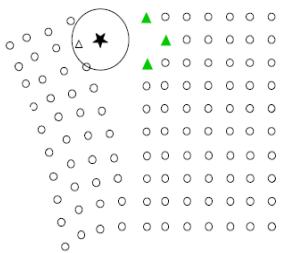
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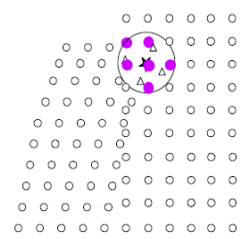
Original



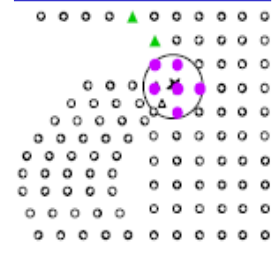
Miss



False



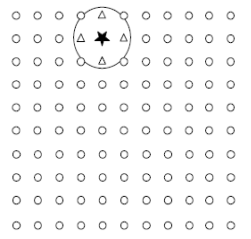
Miss&False



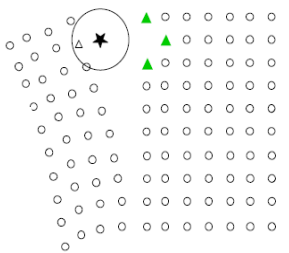
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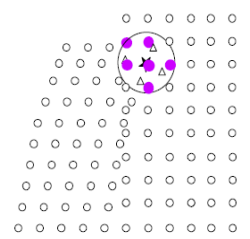
Original



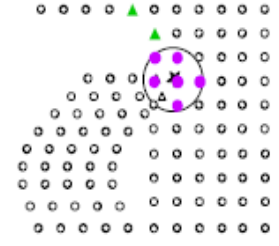
Miss



False



Miss&False



Miss

Miss & False

No distortion

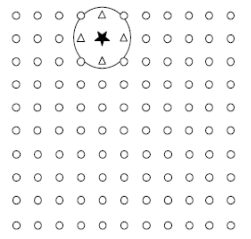
False

Perceptually uniform color map

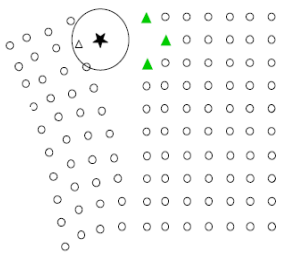
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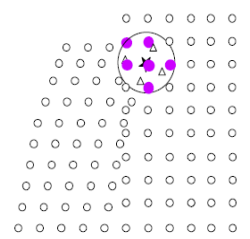
Original



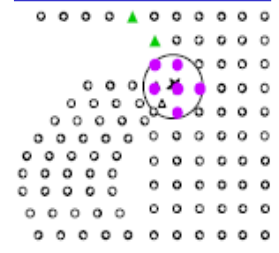
Miss



False



Miss&False



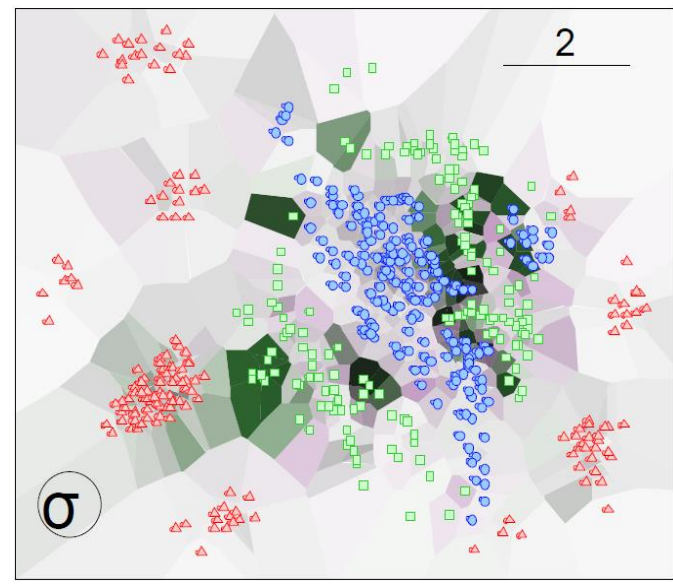
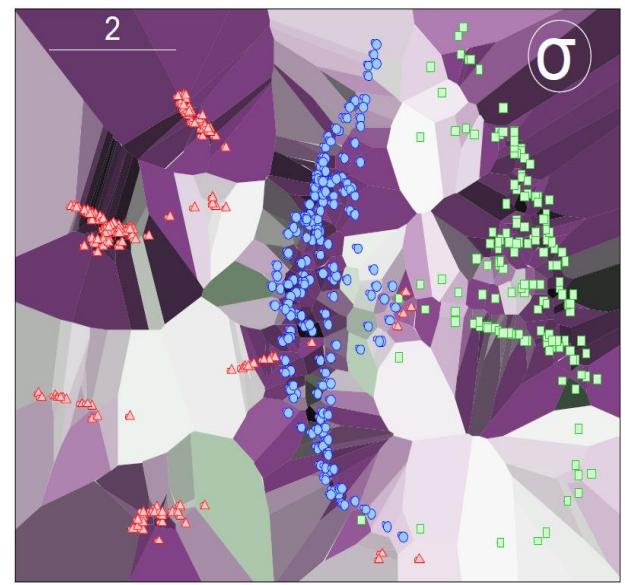
Miss

Miss & False

No distortion

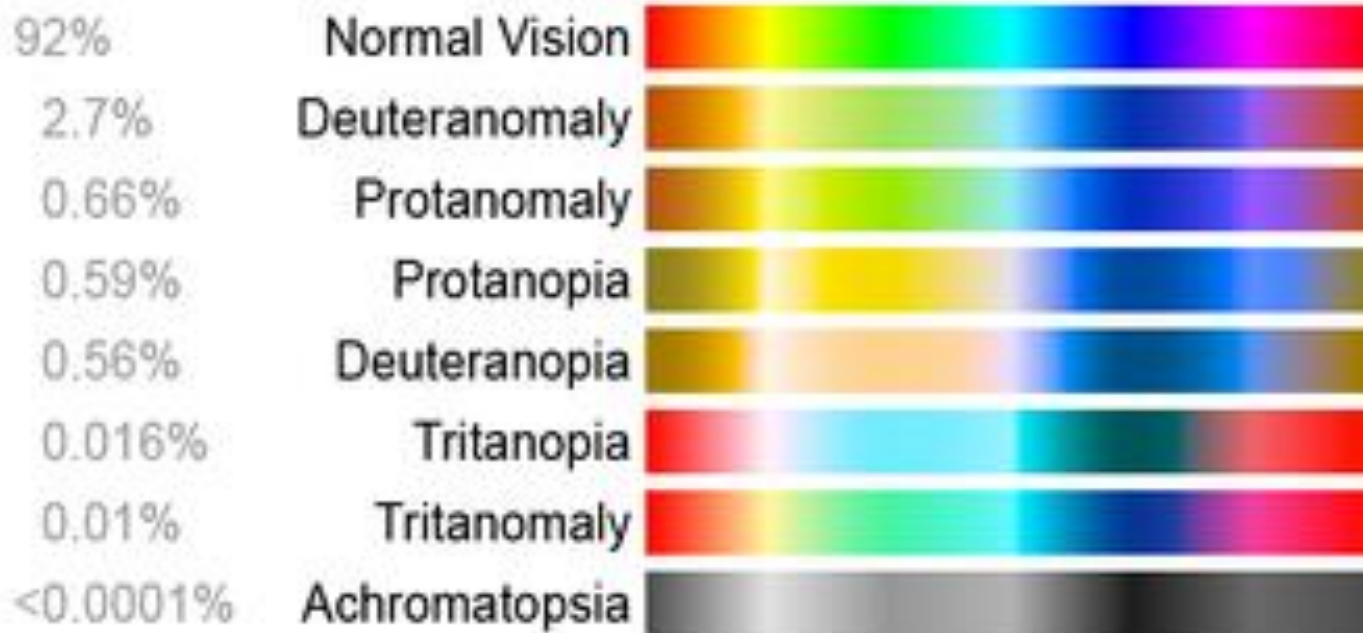
False

Perceptually uniform color map

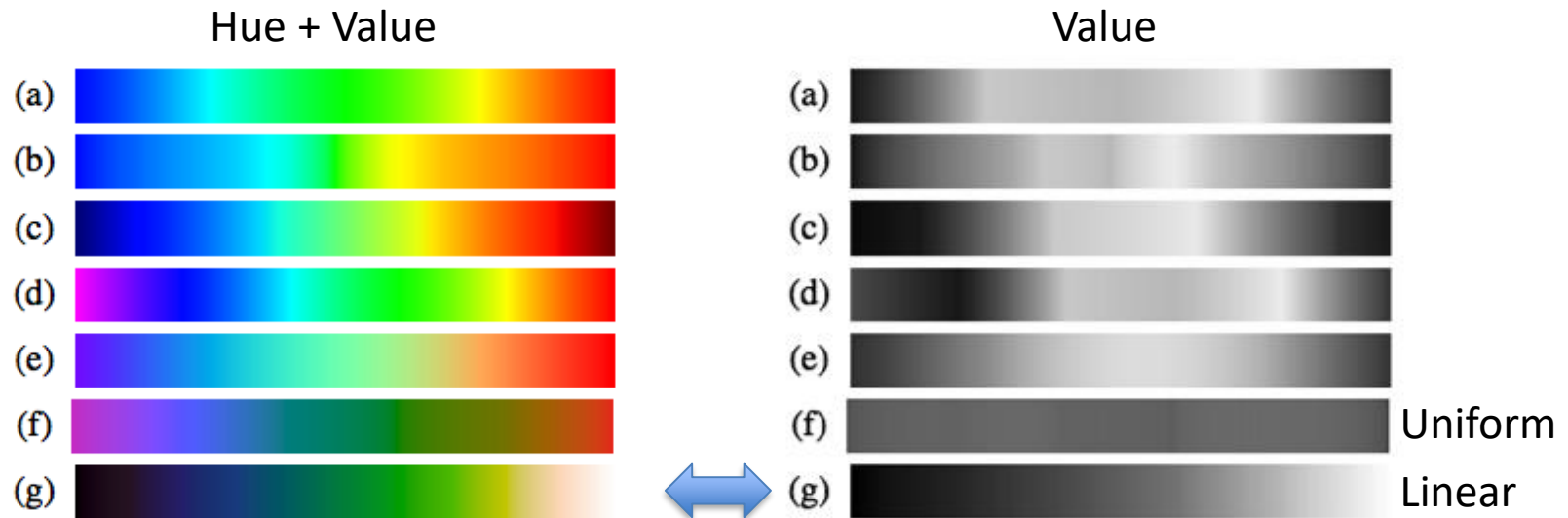




# Color blindness



# So many rainbows...



**Figure 2:** *The term **rainbow color map** can refer to a variety of spectral schemes that do not necessarily suffer from the same problems to the same extent. Notable examples include: (a) the traditional rainbow color map (truncated at blue), (b) Gresh's perceptually linearized rainbow, (c) the jet color map popularized by MATLAB, (d) the traditional rainbow color map (cycling to magenta), (e) the rainbow color map specified by matplotlib, (f) Kindlmann's isoluminant rainbow, and (g) the Kindlmann color map.*

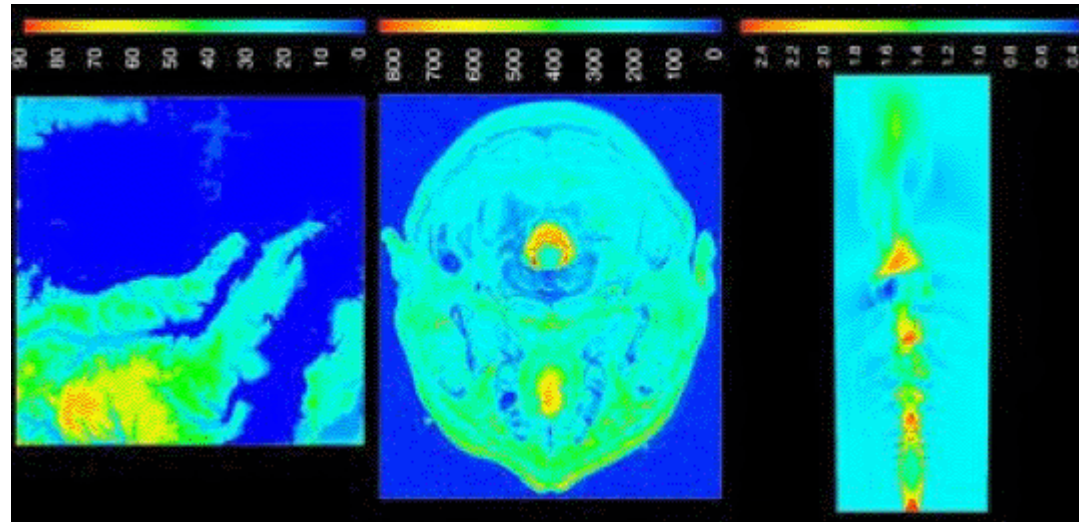


# Visual Perception of colors

<http://www.research.ibm.com/people/l/lloyd/color/color.HTM>

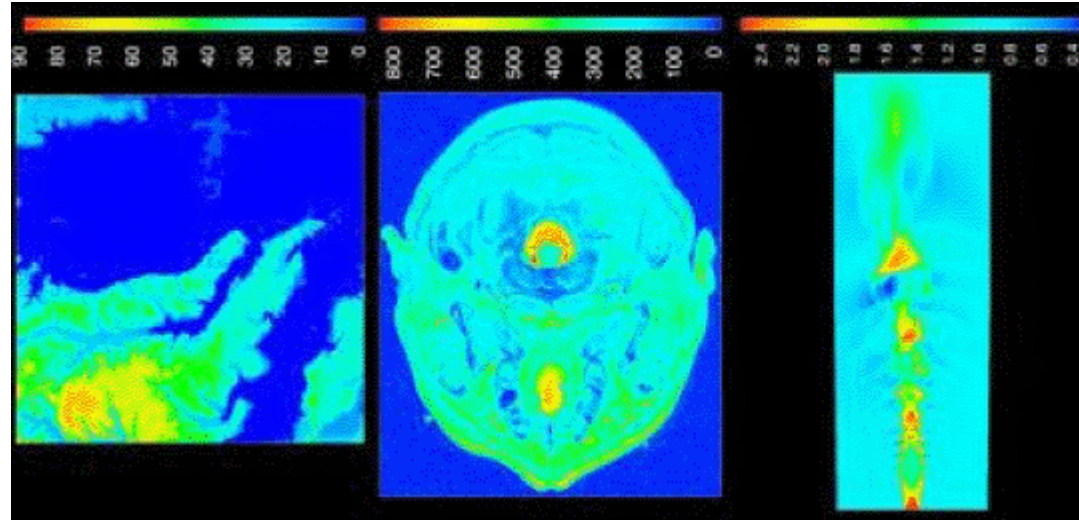
# Visual Perception of colors

- “Rainbow” color scale
  - Uses **Hue** to visualize **quantitative** variable
  - **Irrelevant segmentation**
  - **masking important details**
  - **Is not linear in value**
  
- Encode continuous variable with Value
  - **Value is perceived linearly from black to white (intensity of brightness)**



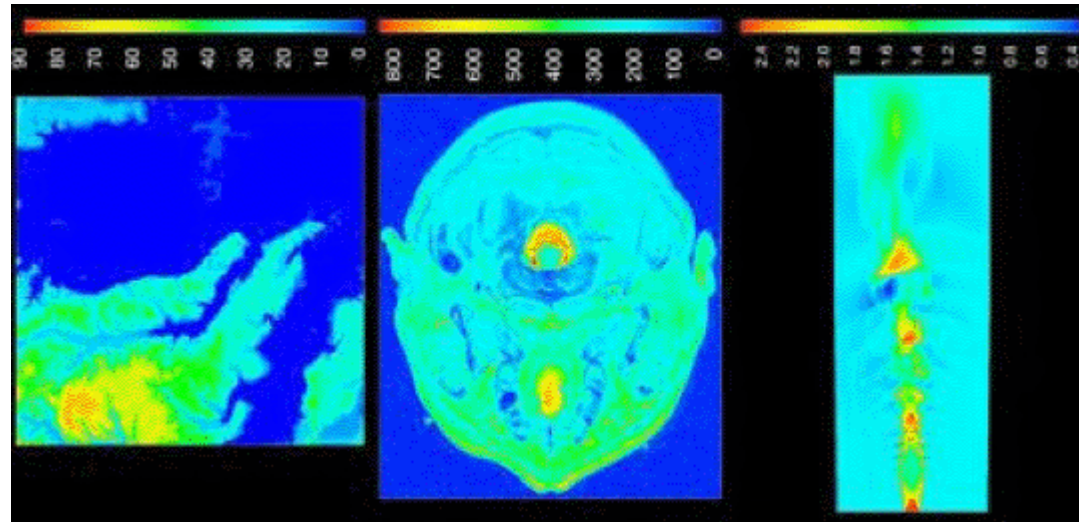
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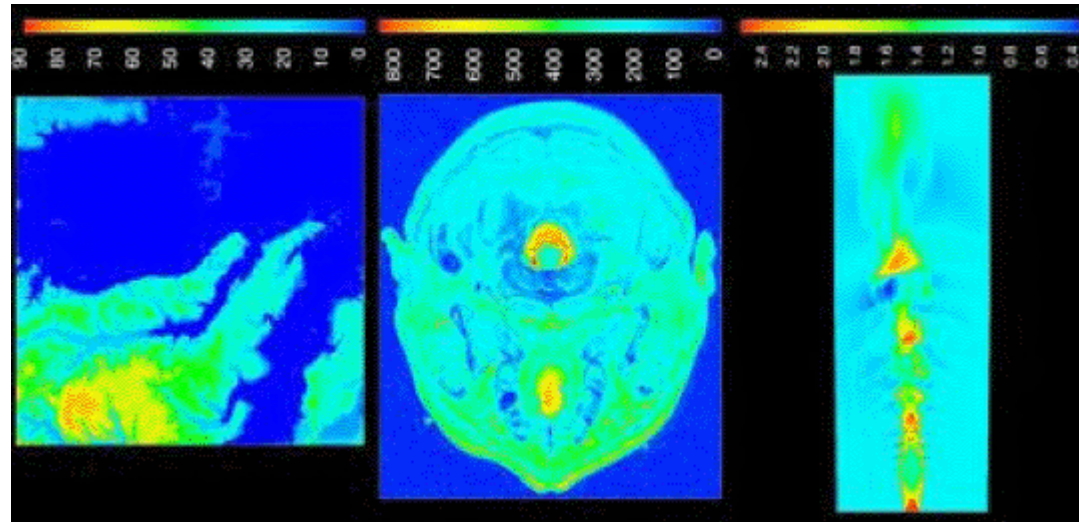
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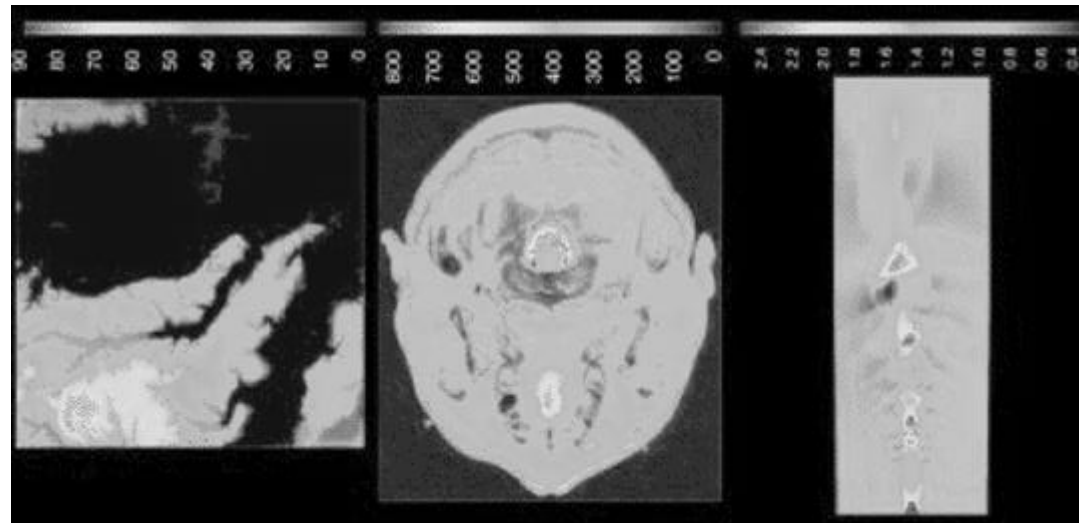
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  - **Is not linear in value**



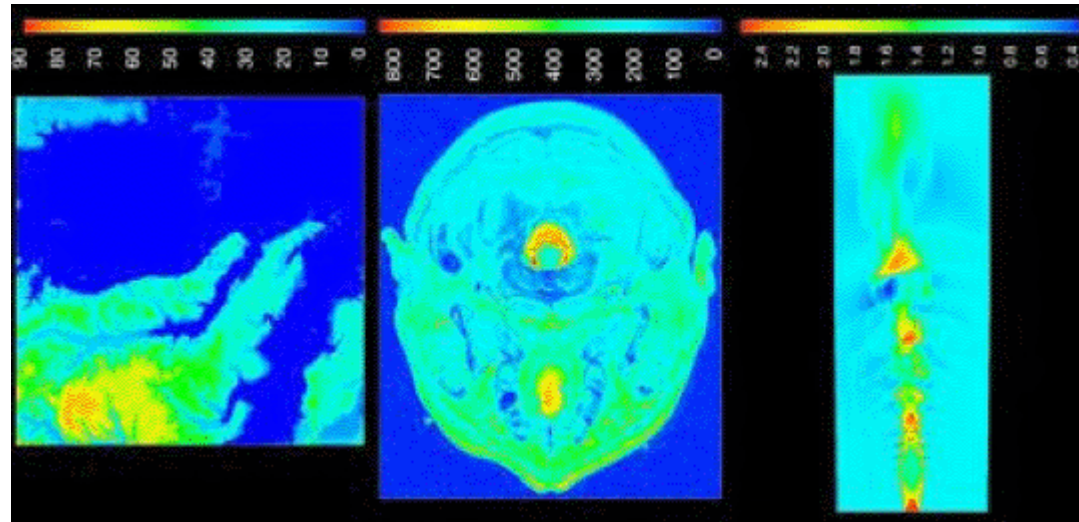
Same rainbow scale turned into greyscale

- Encode continuous variable with Value
  - **Value is perceived linearly from black to white (intensity of brightness)**



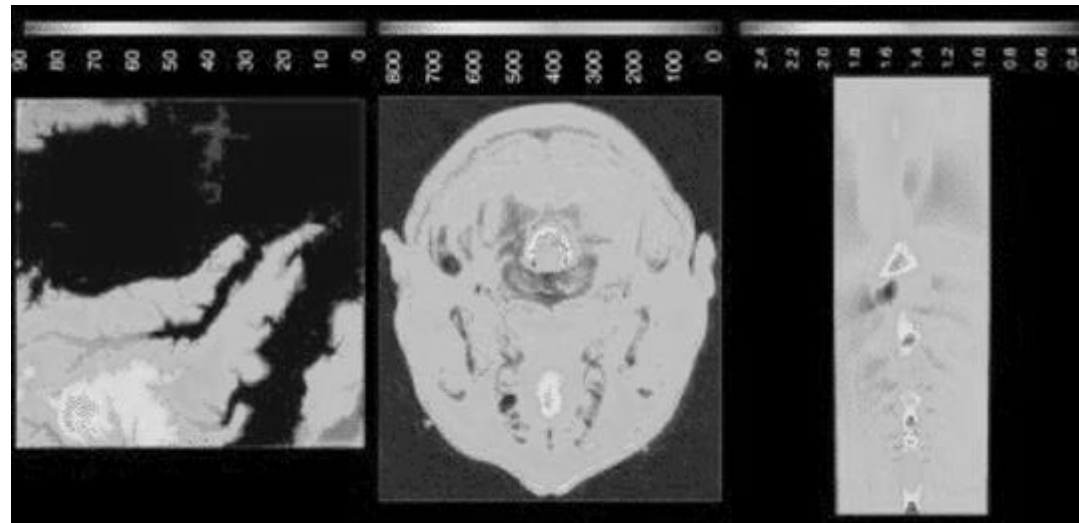
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- “Rainbow” color scale
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Same rainbow scale turned into greyscale

- Encode continuous variable with Value
  - **Value is perceived linearly from black to white (intensity of brightness)**

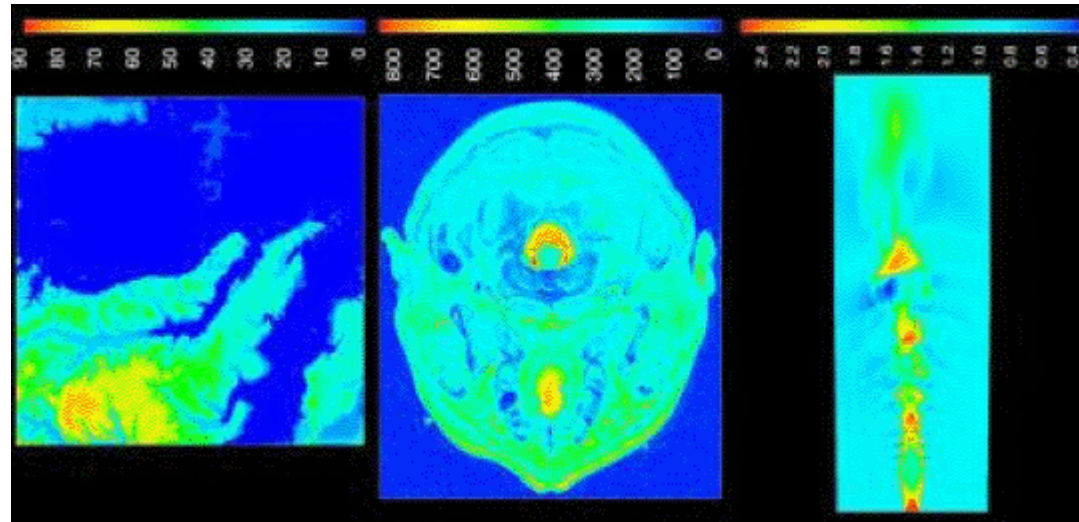




# Visual Perception of colors

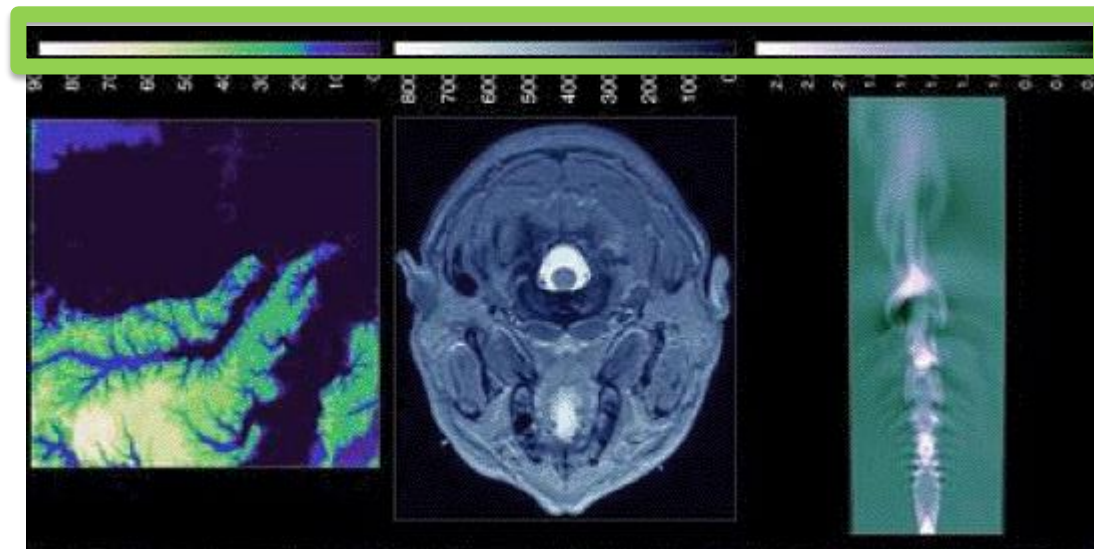
- “Rainbow” color scale

- Uses **Hue** to visualize quantitative variable
- **Irrelevant segmentation**
- **masking important details**
- **Is not linear in value**



- Encode continuous variable with Value

- **Value is perceived linearly from black to white (intensity of brightness)**

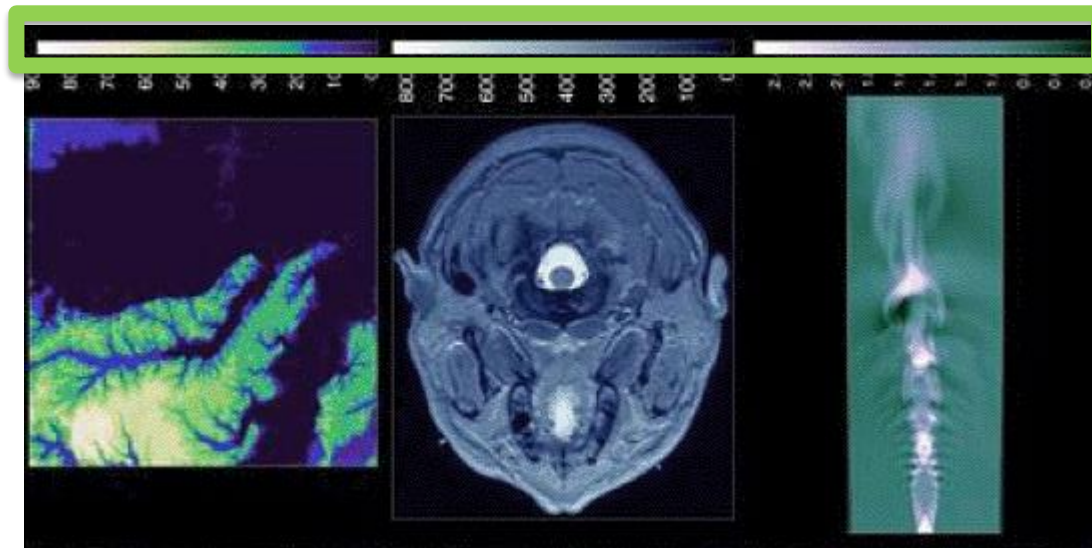
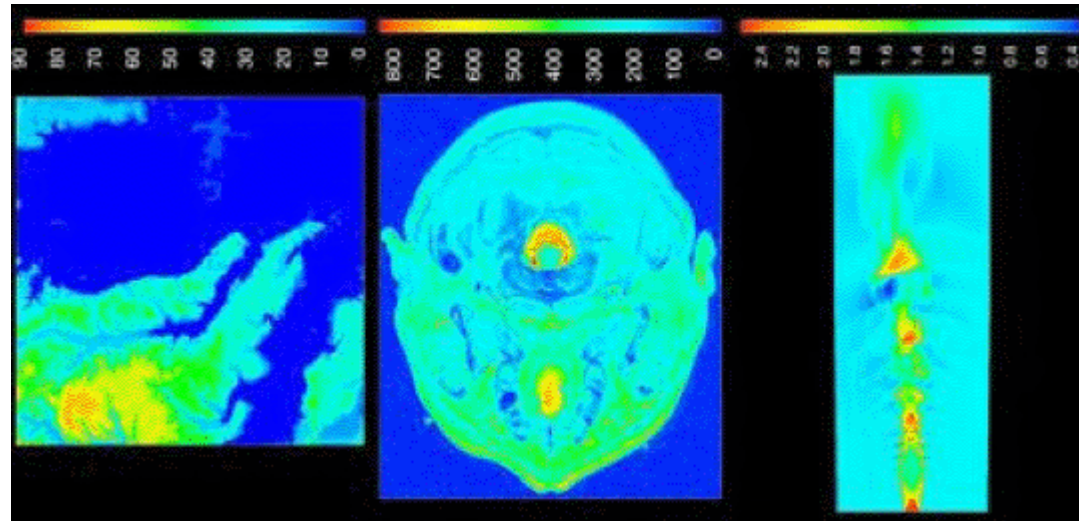


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  - Uses **Hue** to visualize quantitative variable
  - **Irrelevant segmentation**
  - **masking important details**
  - **Is not linear in value**



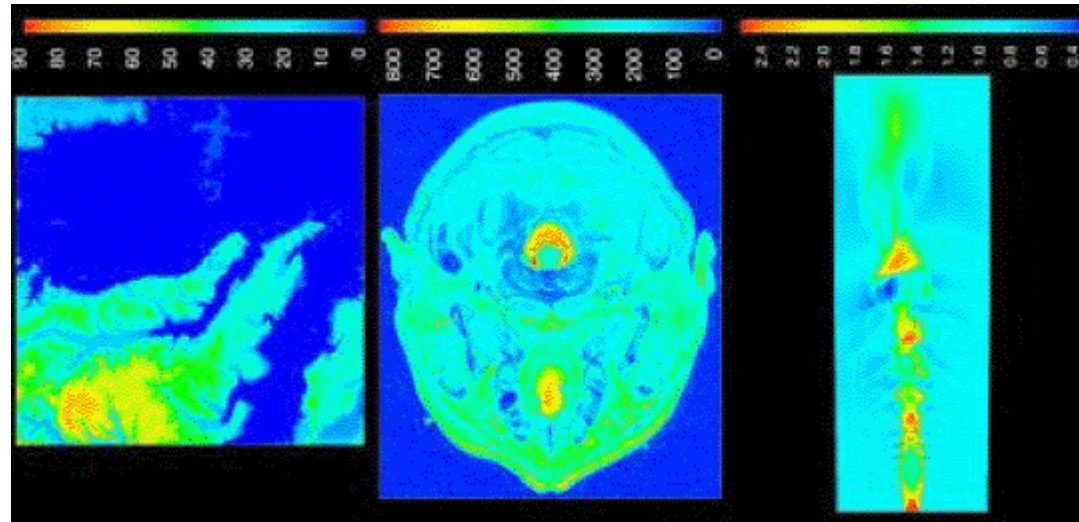
- Encode continuous variable with Value
  - **Value is perceived linearly from black to white (intensity of brightness)**



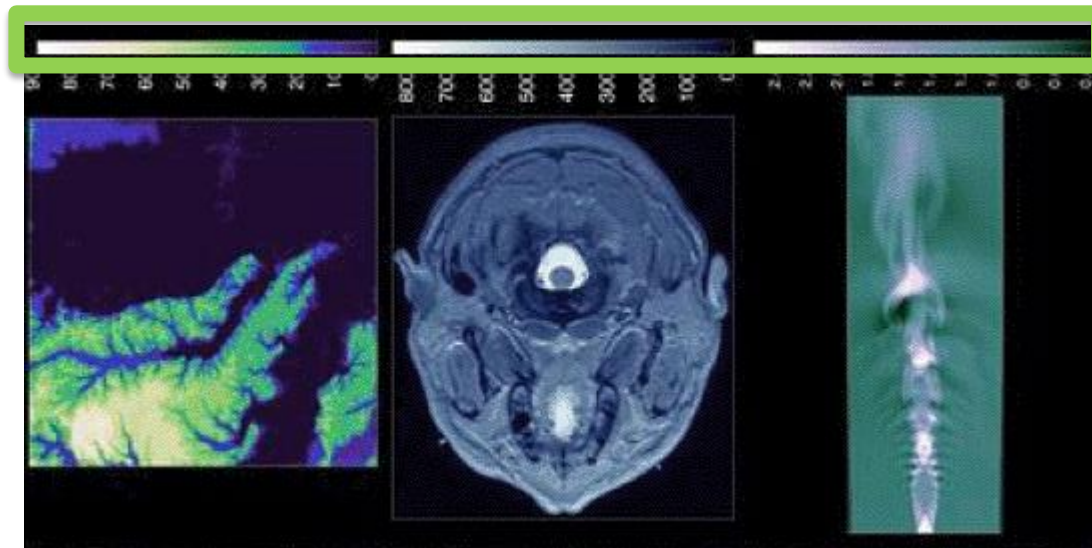
# Visual Perception of colors



- “Rainbow” color scale
  - Uses **Hue** to visualize quantitative variable
  - **Irrelevant segmentation**
  - **masking important details**
  - **Is not linear in value**



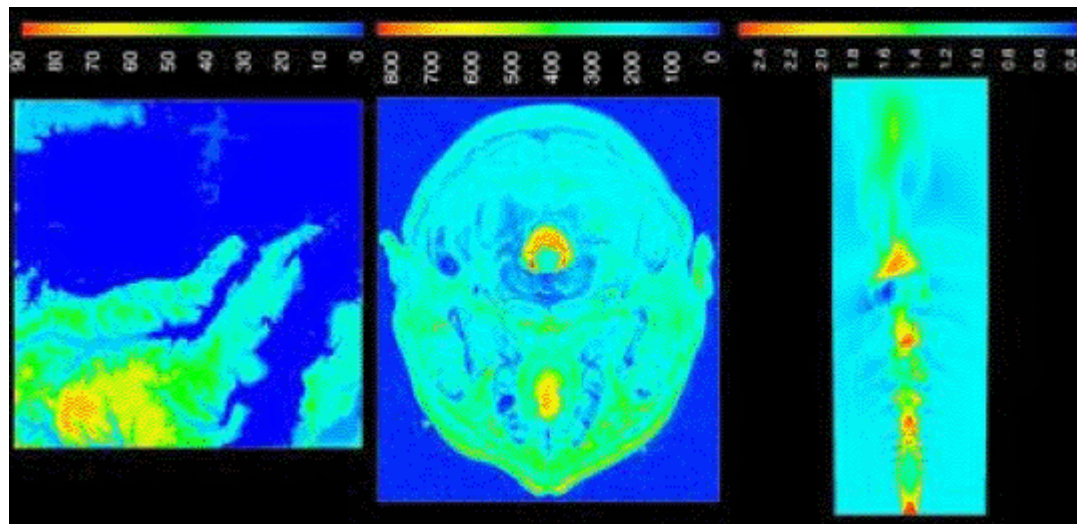
- Encode continuous variable with Value
  - **Value is perceived linearly from black to white (intensity of brightness)**



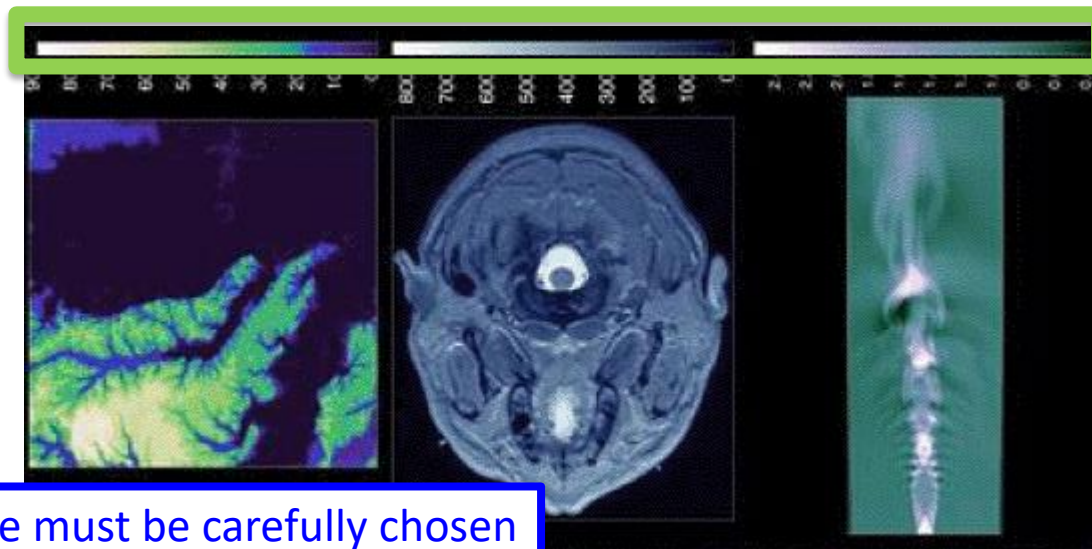
# Visual Perception of colors



- “Rainbow” color scale
  - Uses **Hue** to visualize quantitative variable
  - **Irrelevant segmentation**
  - **masking important details**
  - **Is not linear in value**



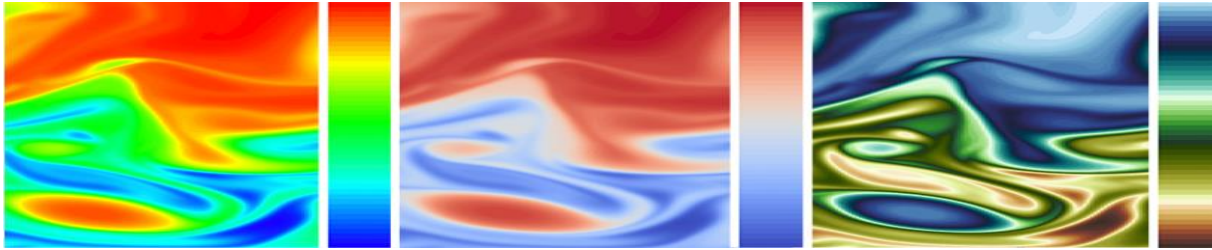
- Encode continuous variable with Value
  - **Value is perceived linearly from black to white (intensity of brightness)**



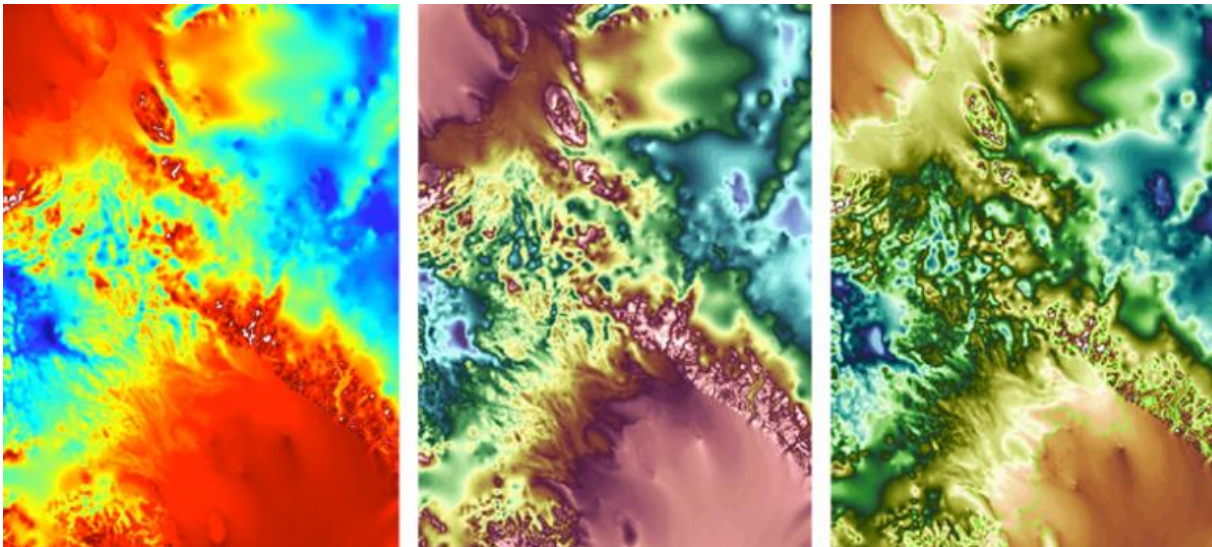
Color scale must be carefully chosen



# Color scales to emphasize specific details

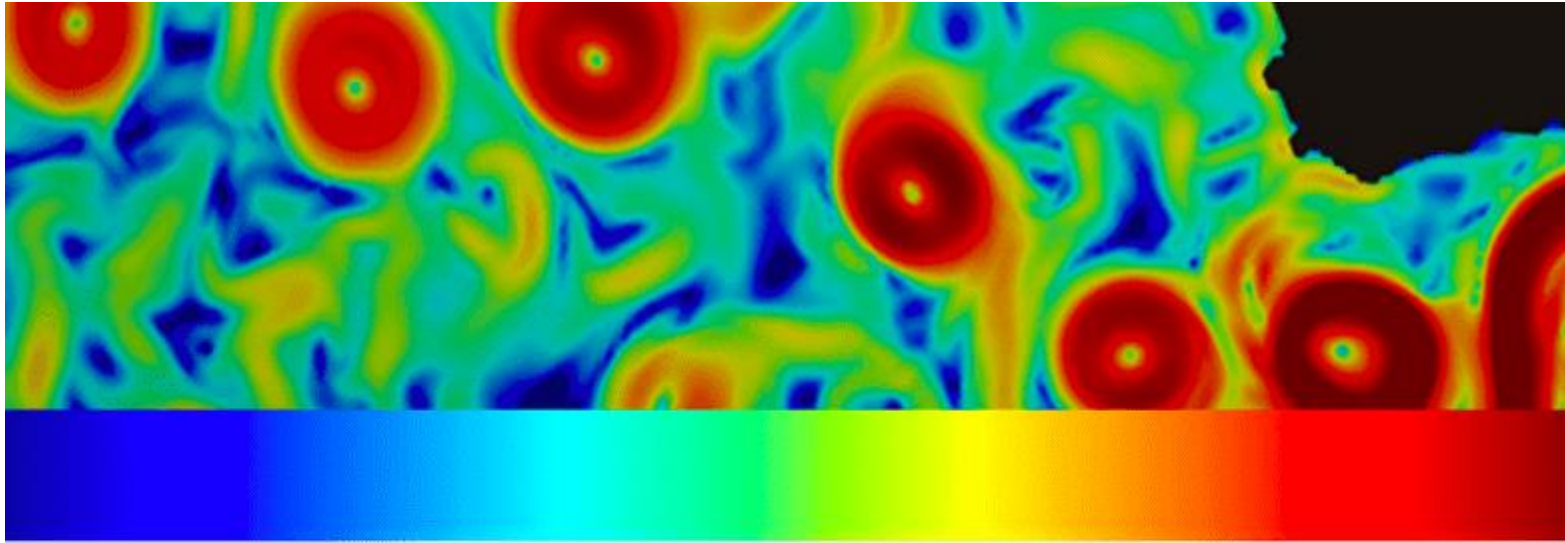


<https://eos.org/features/visualizing-science-how-color-determines-what-we-see>

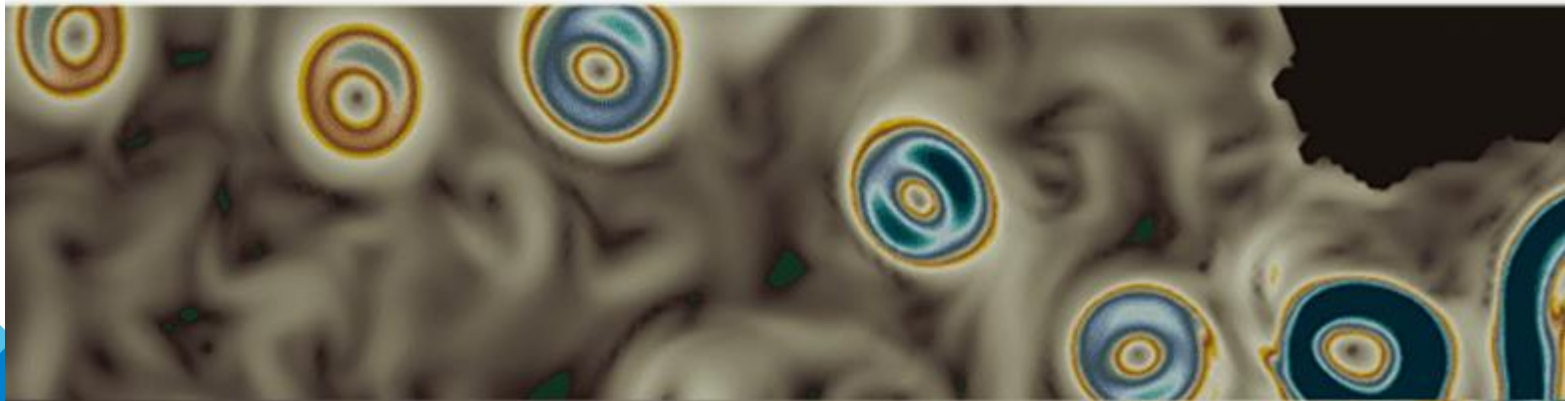


Detail of topography between the Filchner-Ronne and Ross Ice Shelves in West Antarctica. This image illustrates the effects of simultaneous contrast within the traditional rainbow colormap (left), increased detail in a desaturated version of the traditional rainbow (center), and an analogous color palette for greater aesthetic quality as well as discriminatory power (right). Credit: Graphic created by Francesca Samsel with data processed using [E3SM](#)

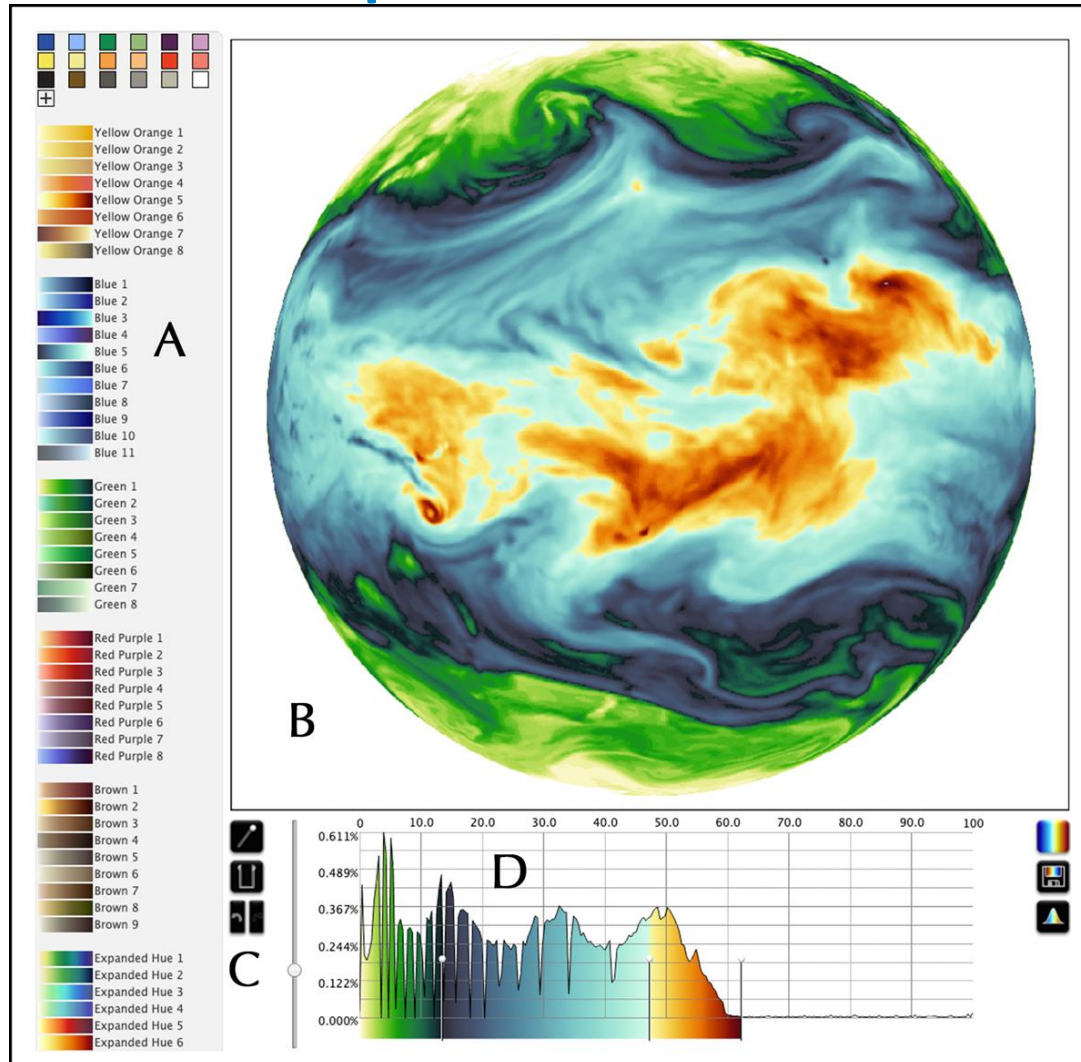
# Color scales to emphasize specific details



<https://eos.org/features/visualizing-science-how-color-determines-what-we-see>



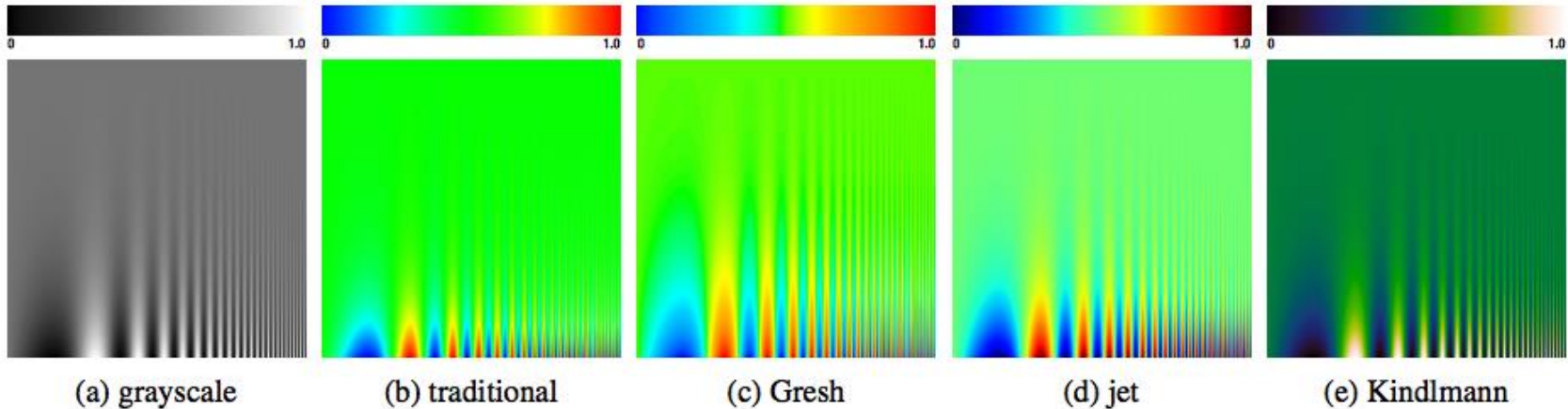
# Color scales to emphasize specific details



<https://eos.org/features/visualizing-science-how-color-determines-what-we-see>

# So many rainbows...

*P.S. Quinan et al. / Examining Implicit Discretization in Spectral Schemes*



**Figure 1:** *Campbell-Robson contrast sensitivity charts visualized using (a) grayscale, (b) the traditional rainbow color map, (c) Gresh's perceptually linearized rainbow, (d) the jet color map, and (e) the Kindlmann color map show pronounced differences in the extents to which rainbow color maps capture data variation. In each image, spatial frequency increases left to right, and contrast increases bottom to top.*



# Picking a categorical color scale

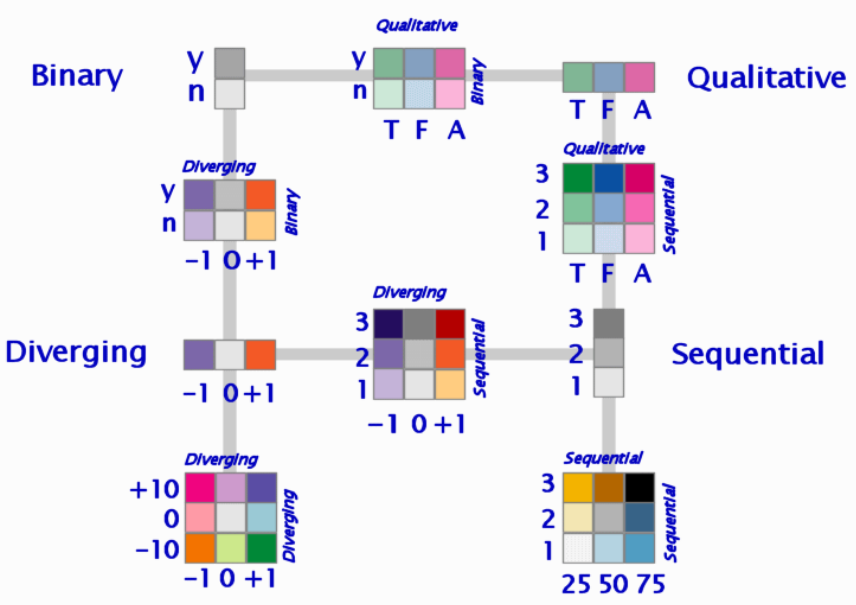
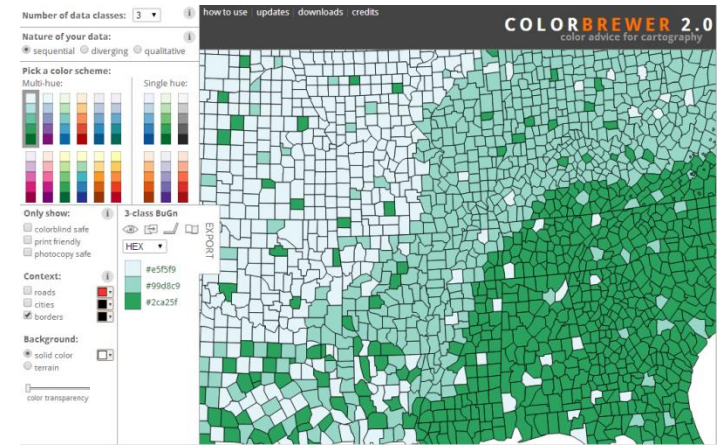
- Colorgorical <http://vrl.cs.brown.edu/color>

The screenshot displays the Colorgorical web application interface. On the left, there is a control panel with a 'Generate' button, a color wheel, and sliders for 'Number of colors' (set to 25), 'Score importance' (Perceptual Distance, Name Difference, Pair Preference, Name Uniqueness), and 'Select hue filters'. The main area shows two results. The top result is for a color space with RGB, Lab, and LCH options. It displays a grid of 25 colors, a warning 'Ran out of colors to add. Try again, or with different settings.', and a list of RGB values: `rgb(120,185,143)`, `rgb(28,91,90)`, `rgb(160,232,91)`, and `rgb(152,36,76)`. The bottom result is for a color space with RGB and LCH options, displaying a grid of 25 colors, a warning, and a list of RGB values: `rgb(33,240,182)` and `rgb(21,73,117)`. Both results include a color palette, a bar chart, and a scatter plot.

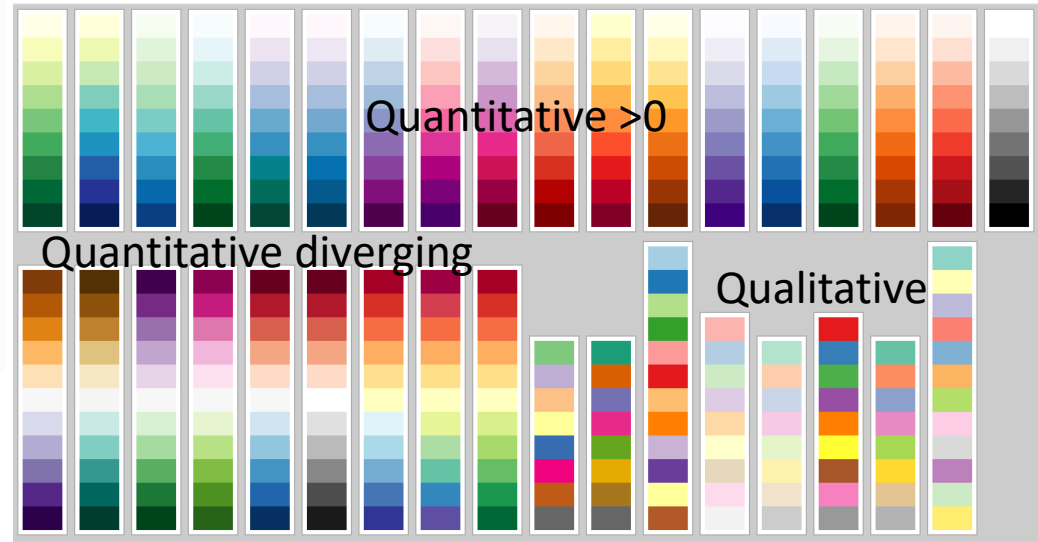


# Choosing a color scale

- Color brewer <http://colorbrewer2.org/>

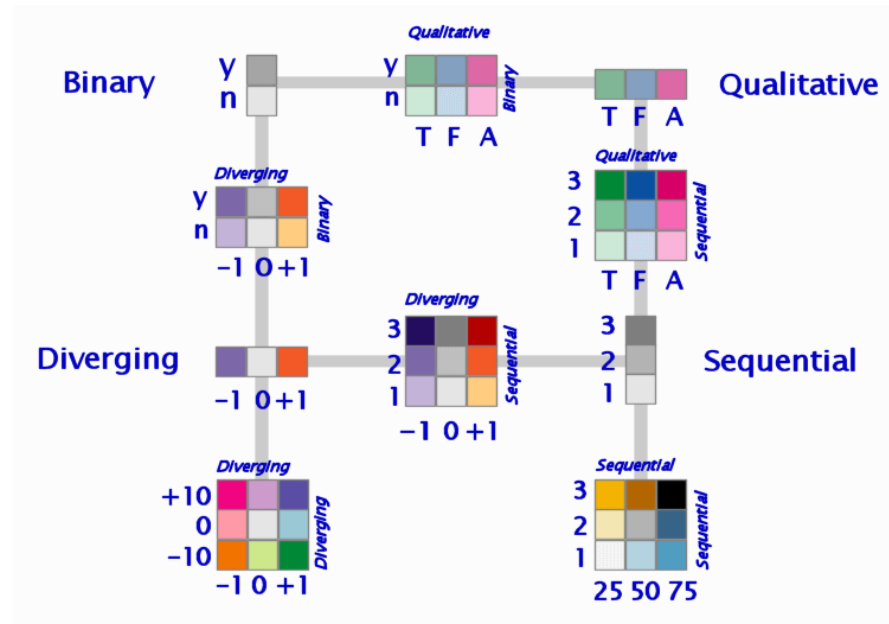


## Every ColorBrewer Scale



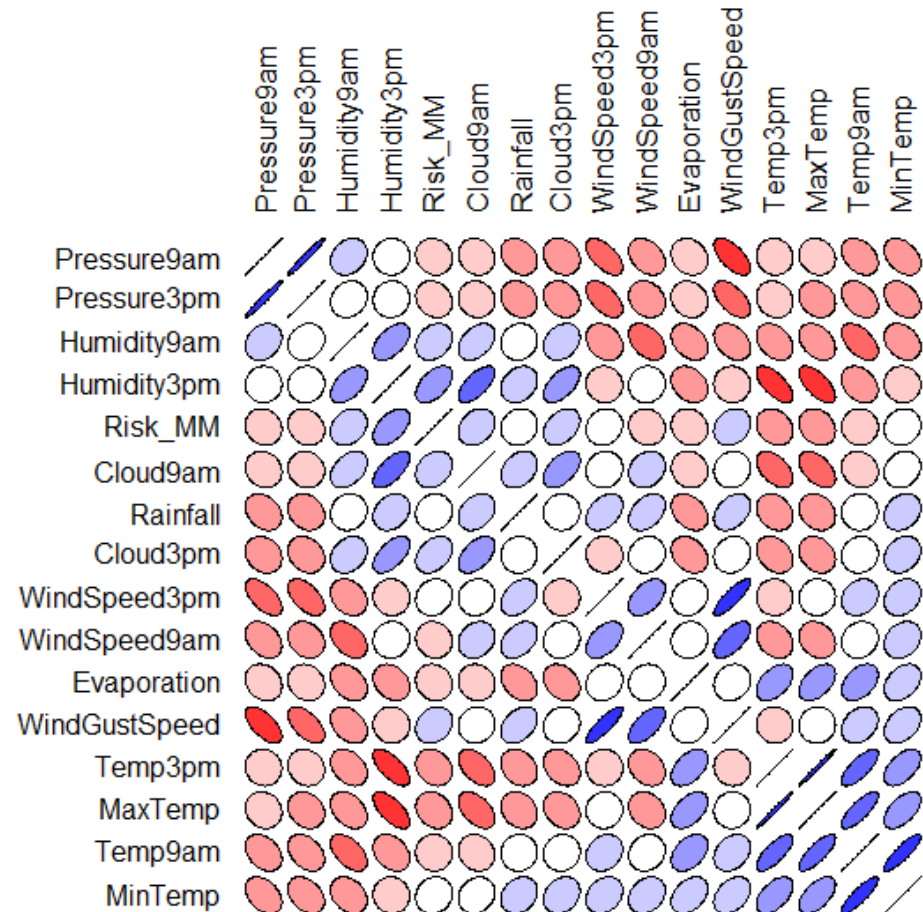
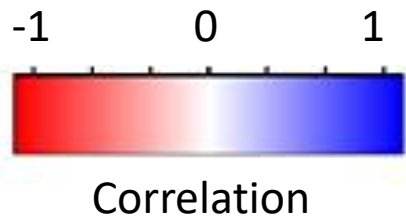
# Your turn...

- Which color scale would you choose for visualizing
  - Correlation coefficient?
  - Periodic table of elements?
  - Density of population on a map?



# Examples of appropriate color scales

**Correlation** is a number between -1 and 1 with a natural “neutral” value  
**Quantitative diverging color scale** is appropriate



# Examples of appropriate color scales

Chemical elements (atoms) can be ordered by their number of protons plus additional periodicity and categorical information.

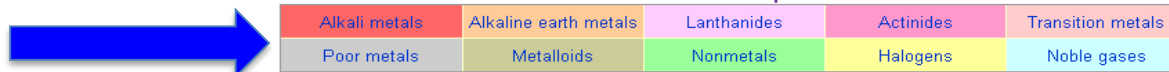
**Space** (quantitative/ordered data) position based on atomic numbers

**Color** is used to encode elements' category as the next prominent information

Group →	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
	I	II											III	IV	V	VI	VII	VIII
↓ Period																		
1	hydrogen 1 H																	helium 2 He
2	lithium 3 Li	beryllium 4 Be											boron 5 B	carbon 6 C	nitrogen 7 N	oxygen 8 O	fluorine 9 F	neon 10 Ne
3	sodium 11 Na	magnesium 12 Mg											aluminium 13 Al	silicon 14 Si	phosphorus 15 P	sulfur 16 S	chlorine 17 Cl	argon 18 Ar
4	potassium 19 K	calcium 20 Ca	scandium 21 Sc	titanium 22 Ti	vanadium 23 V	chromium 24 Cr	manganese 25 Mn	iron 26 Fe	cobalt 27 Co	nickel 28 Ni	copper 29 Cu	zinc 30 Zn	gallium 31 Ga	germanium 32 Ge	arsenic 33 As	selenium 34 Se	bromine 35 Br	krypton 36 Kr
5	rubidium 37 Rb	strontium 38 Sr	yttrium 39 Y	zirconium 40 Zr	niobium 41 Nb	molybdenum 42 Mo	technetium 43 Tc	ruthenium 44 Ru	rhodium 45 Rh	palladium 46 Pd	silver 47 Ag	cadmium 48 Cd	indium 49 In	tin 50 Sn	antimony 51 Sb	tellurium 52 Te	iodine 53 I	xenon 54 Xe
6	caesium 55 Cs	barium 56 Ba	57-71 *	hafnium 72 Hf	tantalum 73 Ta	tungsten 74 W	rhenium 75 Re	osmium 76 Os	iridium 77 Ir	platinum 78 Pt	gold 79 Au	mercury 80 Hg	thallium 81 Tl	lead 82 Pb	bismuth 83 Bi	polonium 84 Po	astatine 85 At	radon 86 Rn
7	francium 87 Fr	radium 88 Ra	89-103 **	rutherfordium 104 Rf	dubnium 105 Db	seaborgium 106 Sg	bohrium 107 Bh	hassium 108 Hs	meitnerium 109 Mt	darmstadtium 110 Ds	roentgenium 111 Rg	ununbium 112 Uub	ununtrium 113 Uut	ununquadium 114 Uuq	ununpentium 115 Uup	ununhexium 116 Uuh	ununseptium 117 Uus	ununoctium 118 Uuo
* Lanthanides	lanthanum 57 La	cerium 58 Ce	praseodymium 59 Pr	neodymium 60 Nd	promethium 61 Pm	samarium 62 Sm	europium 63 Eu	gadolinium 64 Gd	terbium 65 Tb	dysprosium 66 Dy	holmium 67 Ho	erbium 68 Er	thulium 69 Tm	ytterbium 70 Yb	lutetium 71 Lu			
** Actinides	actinium 89 Ac	thorium 90 Th	protactinium 91 Pa	uranium 92 U	neptunium 93 Np	plutonium 94 Pu	americium 95 Am	curium 96 Cm	berkelium 97 Bk	californium 98 Cf	einsteinium 99 Es	fermium 100 Fm	mendelevium 101 Md	nobelium 102 No	lawrencium 103 Lr			

Chemical elements

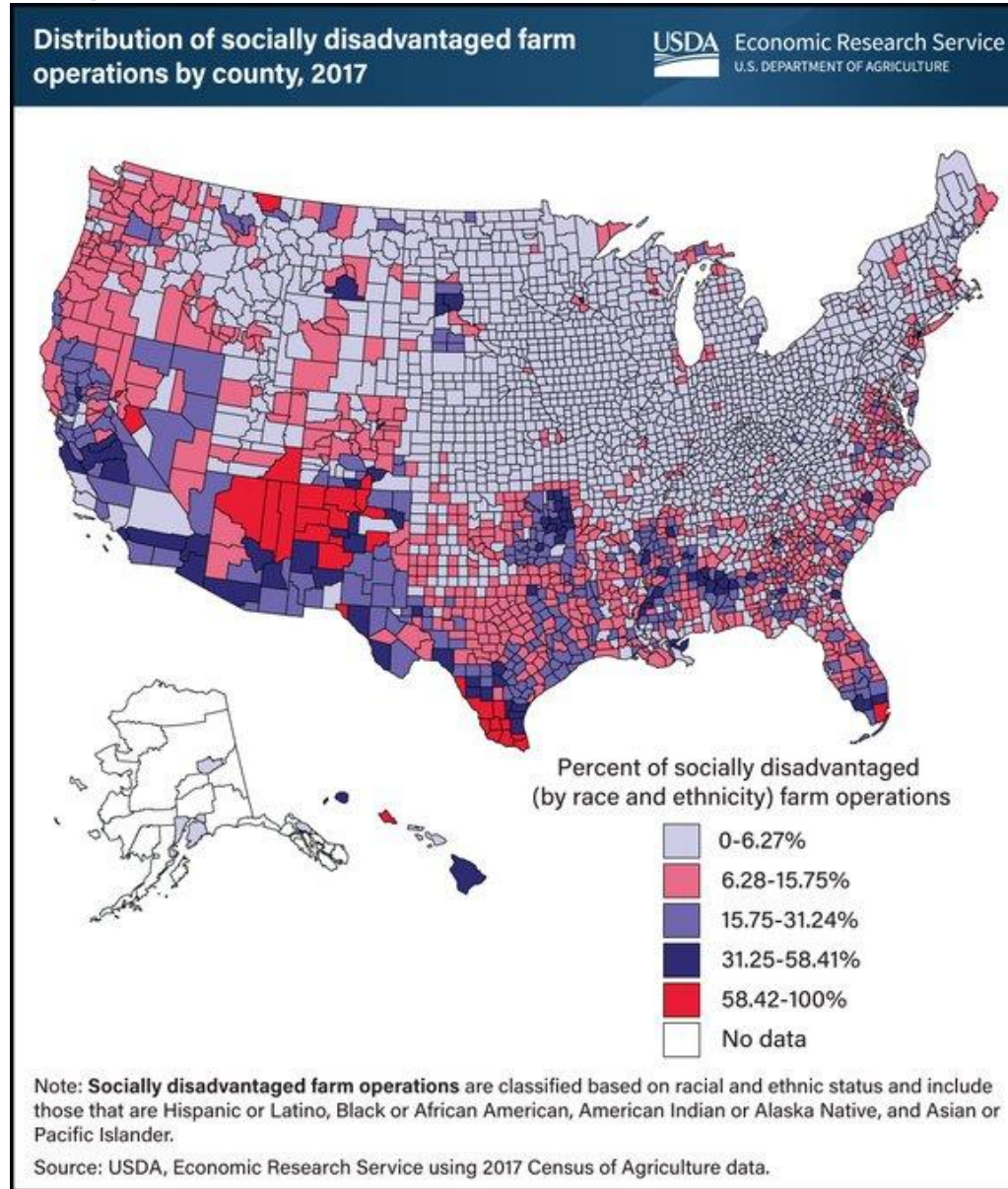
Chemical series of the periodic table



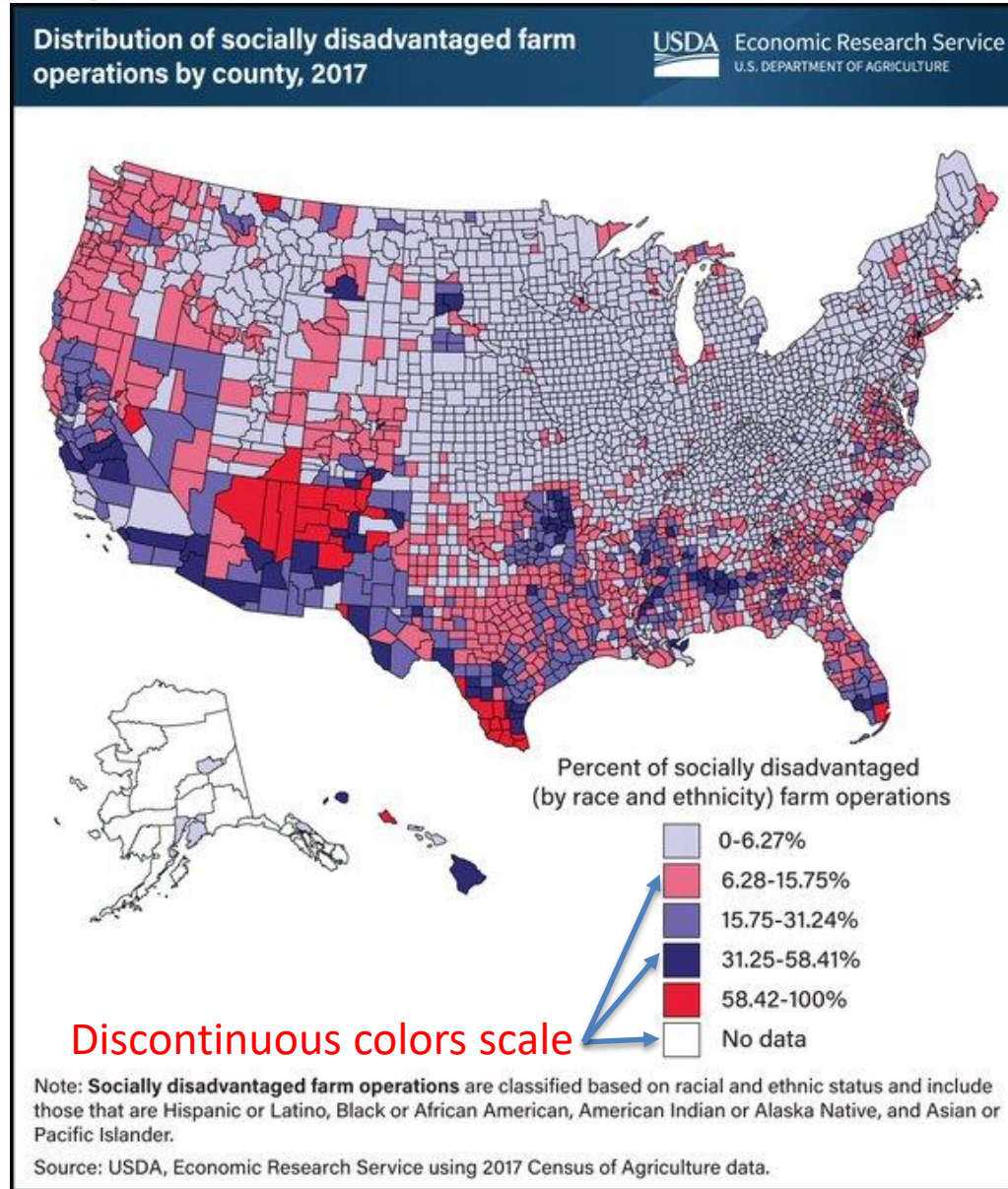
Here is the color scale

[https://en.wikipedia.org/wiki/Periodic\\_table](https://en.wikipedia.org/wiki/Periodic_table)

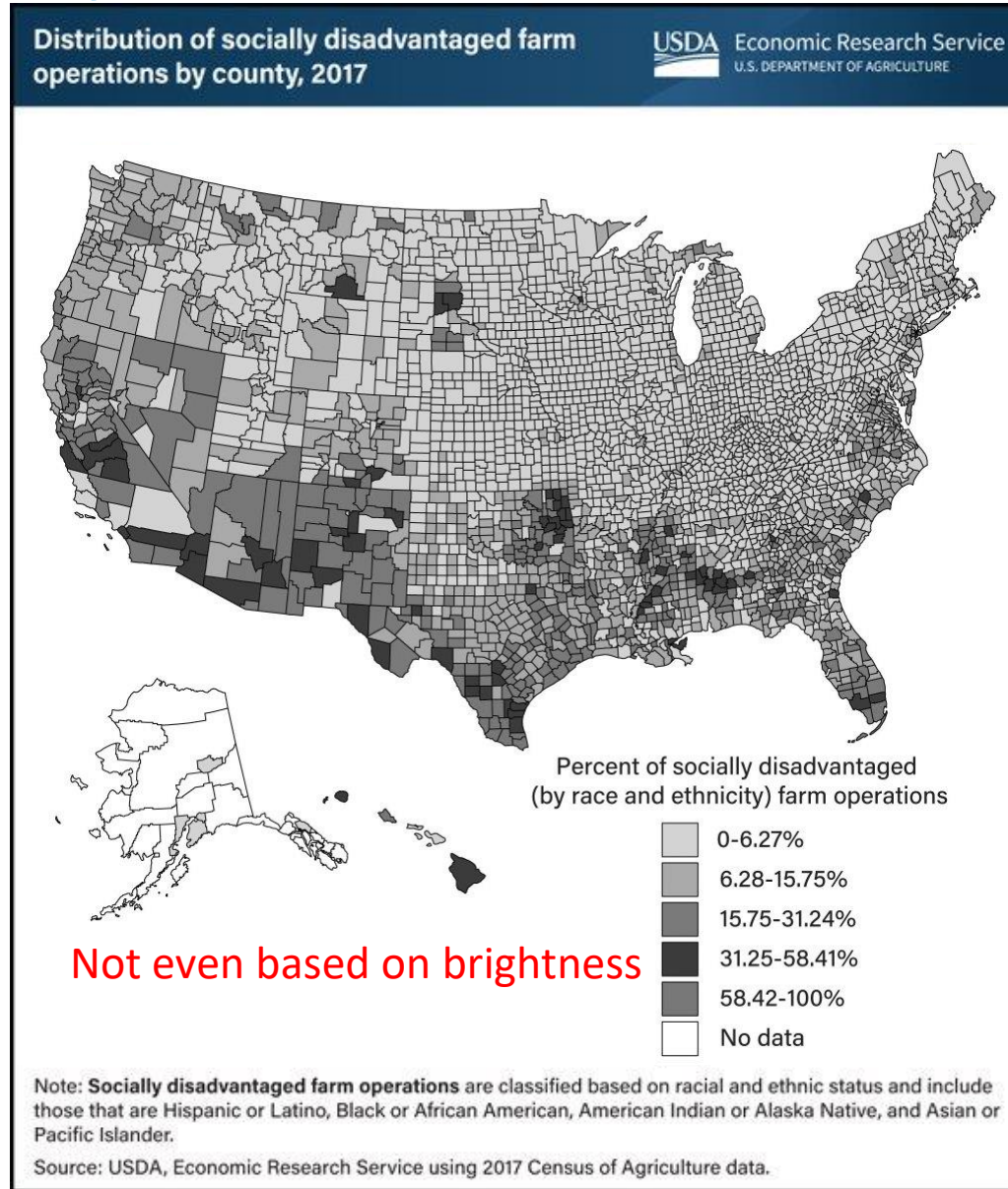
# What do you think of the color scale?



# What do you think of the color scale?

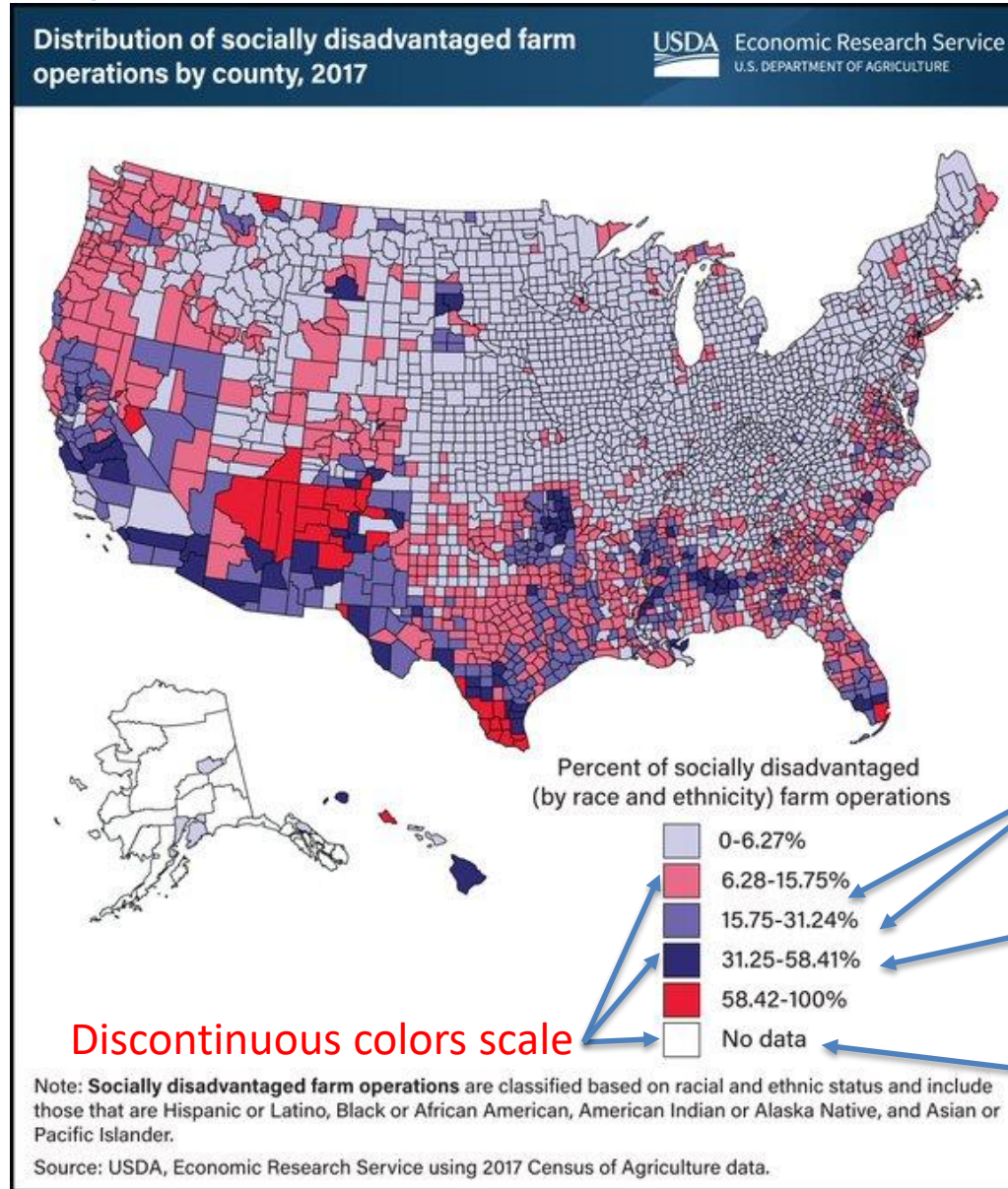


# What do you think of the color scale?





# What do you think of the color scale?



Discontinuous colors scale

Non linear (log scale)

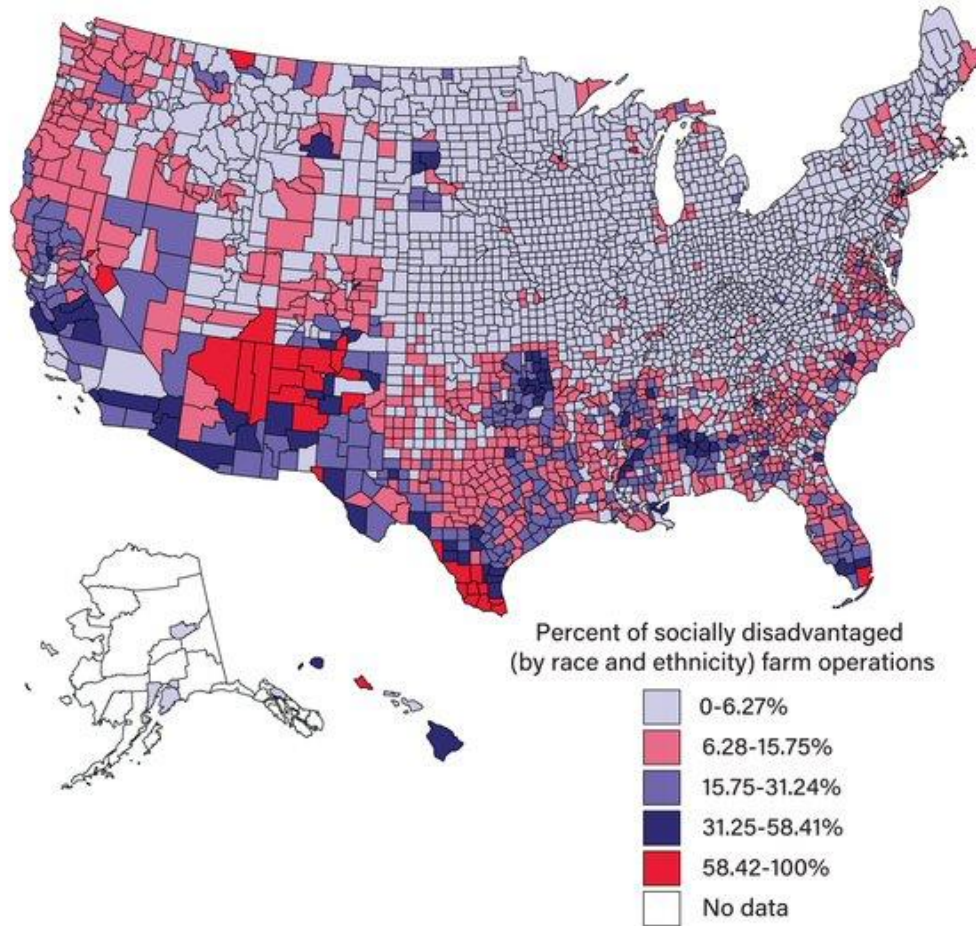
Hard to read values, unnecessary precision

Non-neutral color

# Picking a better color scale

Distribution of socially disadvantaged farm operations by county, 2017

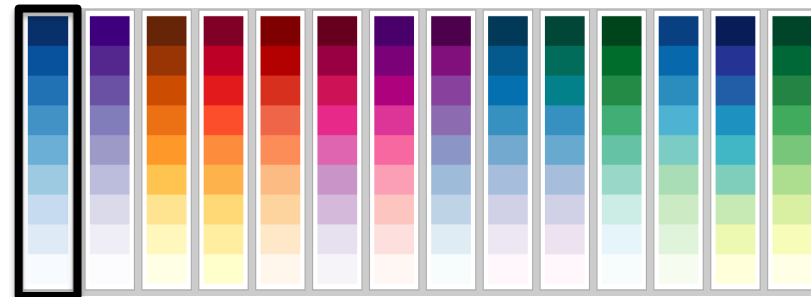
USDA Economic Research Service  
U.S. DEPARTMENT OF AGRICULTURE



Note: **Socially disadvantaged farm operations** are classified based on racial and ethnic status and include those that are Hispanic or Latino, Black or African American, American Indian or Alaska Native, and Asian or Pacific Islander.

Source: USDA, Economic Research Service using 2017 Census of Agriculture data.

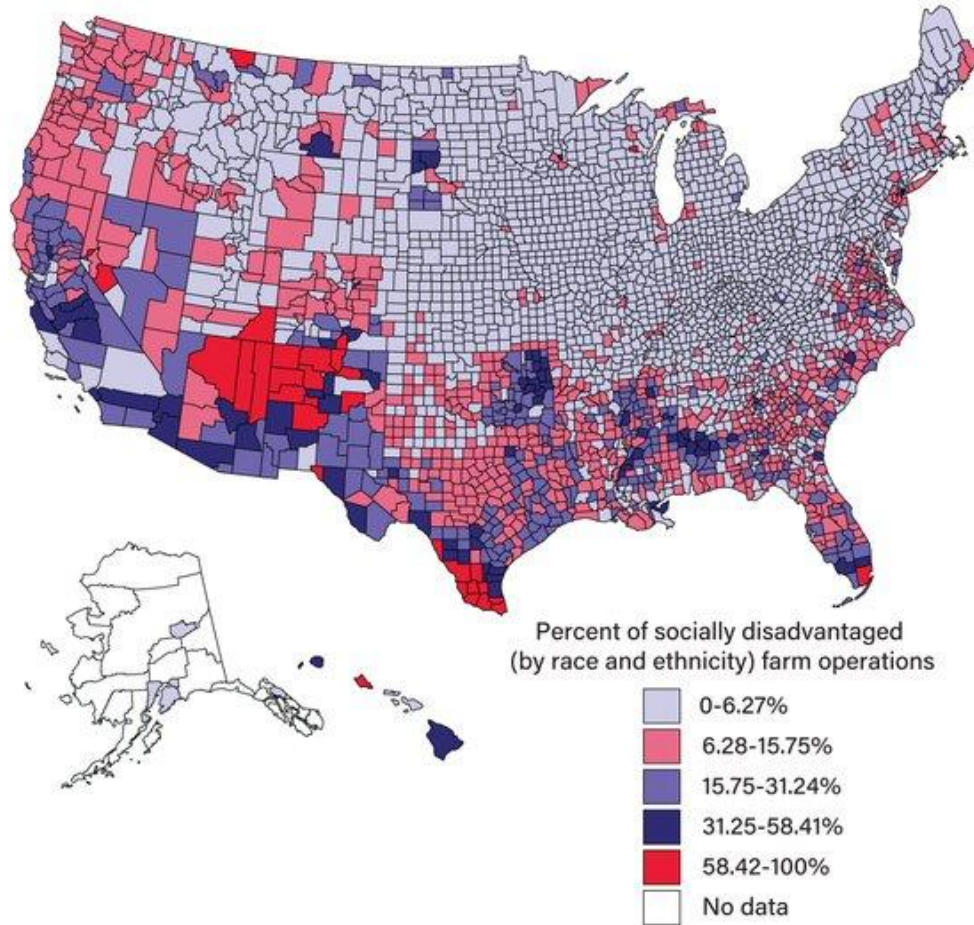
Pick a **continuous** color scale



# Picking a better color scale

Distribution of socially disadvantaged farm operations by county, 2017

USDA Economic Research Service  
U.S. DEPARTMENT OF AGRICULTURE



Note: **Socially disadvantaged farm operations** are classified based on racial and ethnic status and include those that are Hispanic or Latino, Black or African American, American Indian or Alaska Native, and Asian or Pacific Islander.

Source: USDA, Economic Research Service using 2017 Census of Agriculture data.

Make it **non-linear (log)**

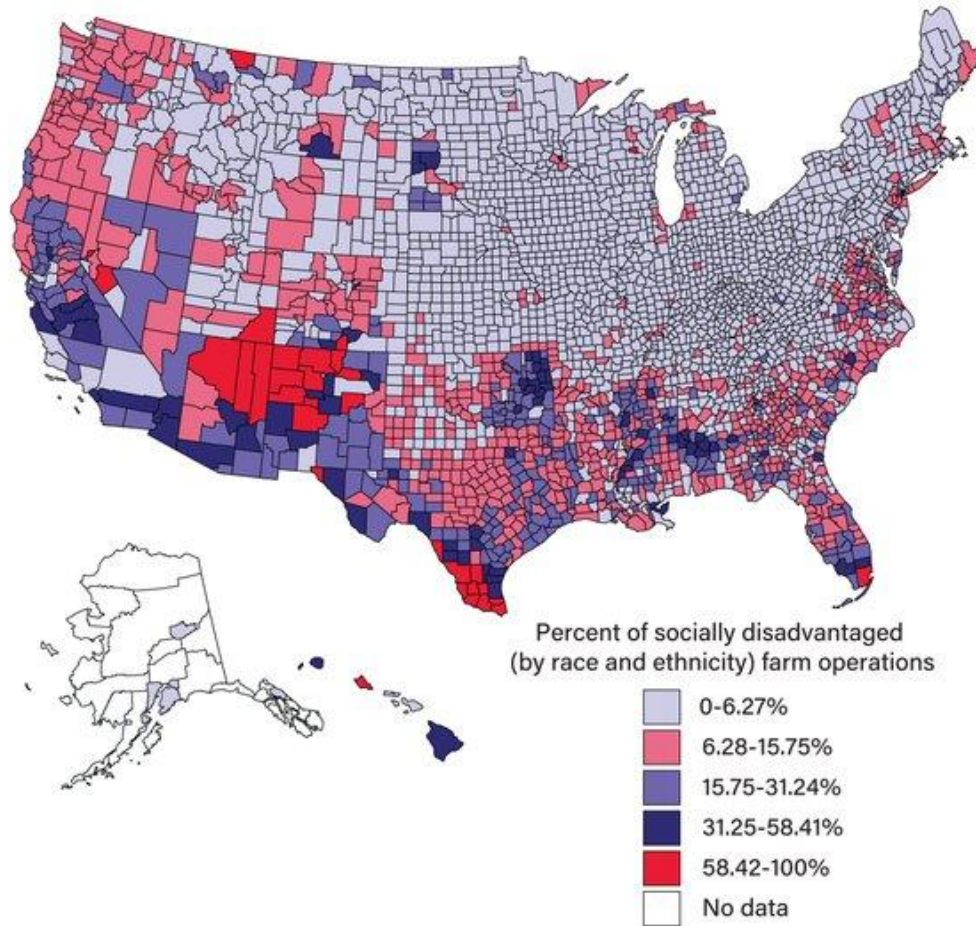
so segment length  
match with ranges



# Picking a better color scale

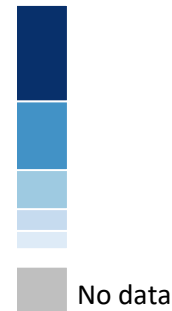
Distribution of socially disadvantaged farm operations by county, 2017

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U.S. DEPARTMENT OF AGRICULTURE



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Source: USDA, Economic Research Service using 2017 Census of Agriculture data.



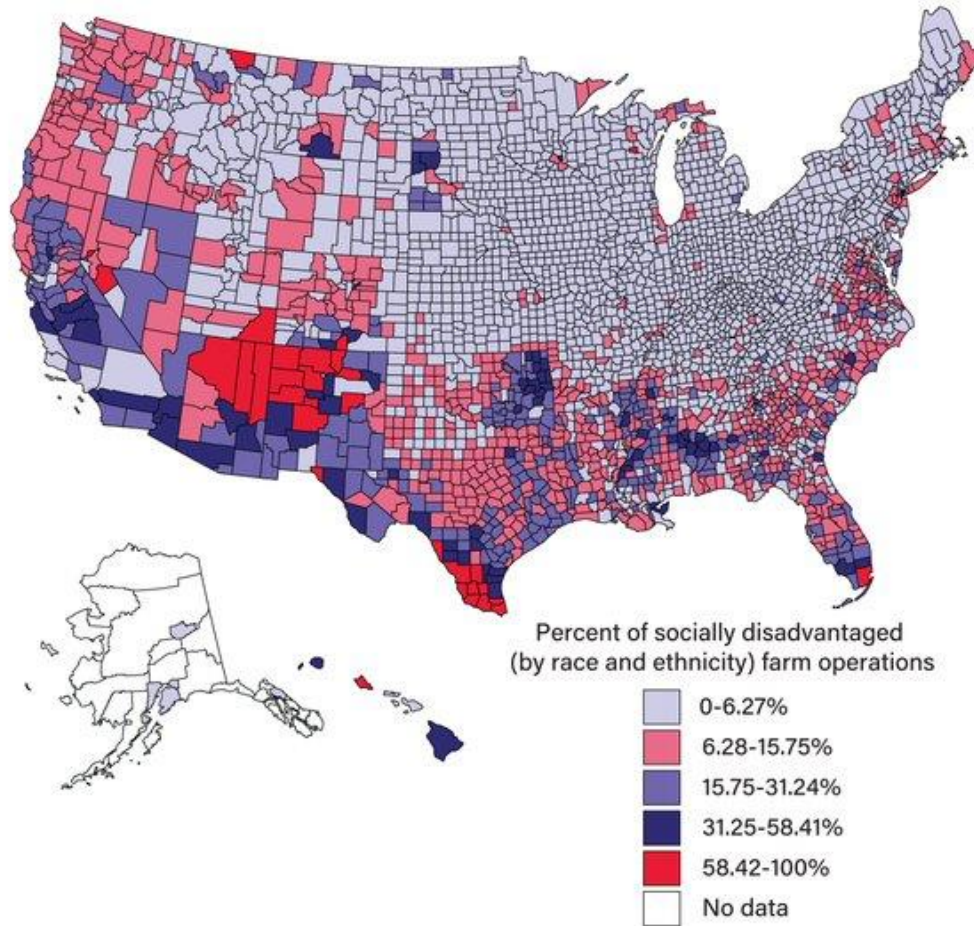
pick a neutral tone **not linked** to the rest of the color scale



# Picking a better color scale

Distribution of socially disadvantaged farm operations by county, 2017

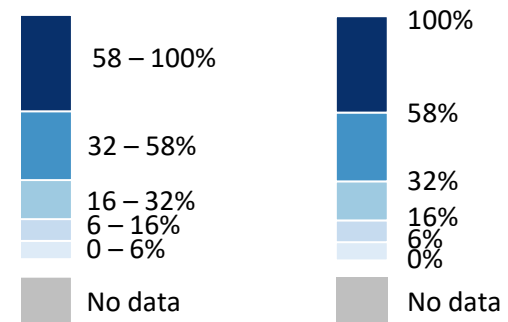
USDA Economic Research Service  
U.S. DEPARTMENT OF AGRICULTURE



Note: **Socially disadvantaged farm operations** are classified based on racial and ethnic status and include those that are Hispanic or Latino, Black or African American, American Indian or Alaska Native, and Asian or Pacific Islander.

Source: USDA, Economic Research Service using 2017 Census of Agriculture data.

Use easier to read values

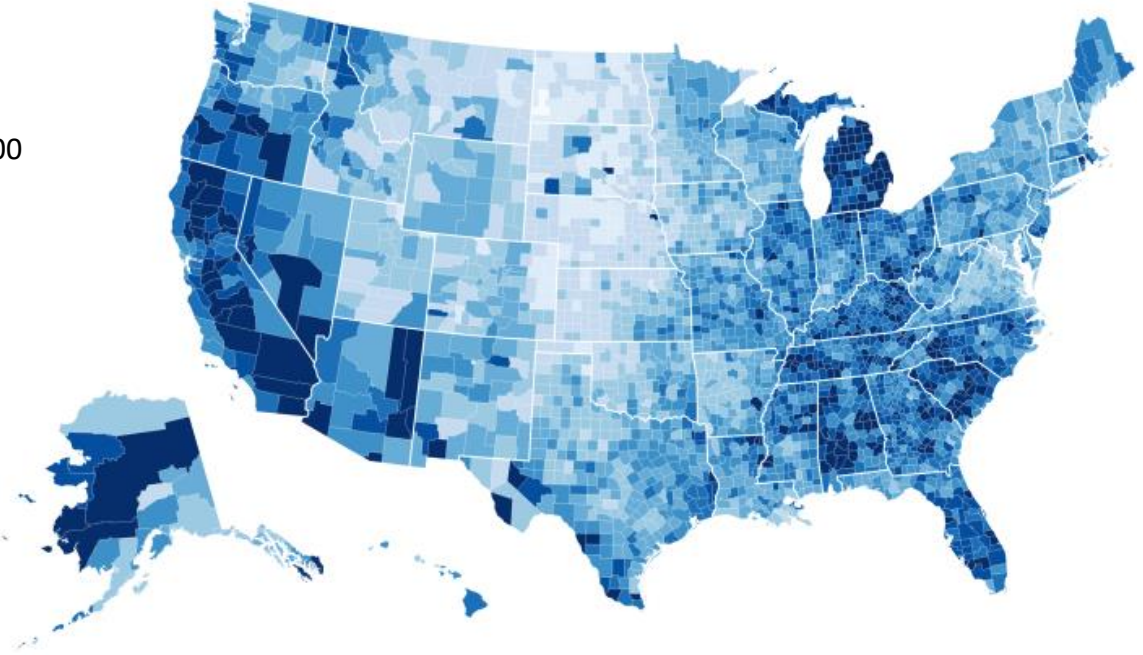


# Examples of appropriate color scales

Population density is a positive real number

**Quantitative non-diverging color scale** is appropriate

Quantitative



<http://mbostock.github.io/d3/talk/20111018/choropleth.html>

# Color-code your tables!

	Questions							
	Q1: Will the user realistically be trying to do this action?		Q2: Is the action visible?		Q3: Will user recognize the action as being the correct one?		Q4: Will the user understand the feedback/ is the feedback appropriate?	
	Yes	No	Yes	No	Yes	No	Yes	No
<b>Task 1</b>	5	1	6	0	4	2	3	3
<b>Task 2</b>	5	1	3	3	4	2	4	2
<b>Task 3</b>	4	2	5	1	5	1	6	0

# Well...

	Questions							
	Q1: Will the user realistically be trying to do this action?		Q2: Is the action visible?		Q3: Will user recognize the action as being the correct one?		Q4: Will the user understand the feedback/ is the feedback appropriate?	
	Yes	No	Yes	No	Yes	No	Yes	No
<b>Task 1</b>	5	1	6	0	4	2	3	3
<b>Task 2</b>	5	1	3	3	4	2	4	2
<b>Task 3</b>	4	2	5	1	5	1	6	0



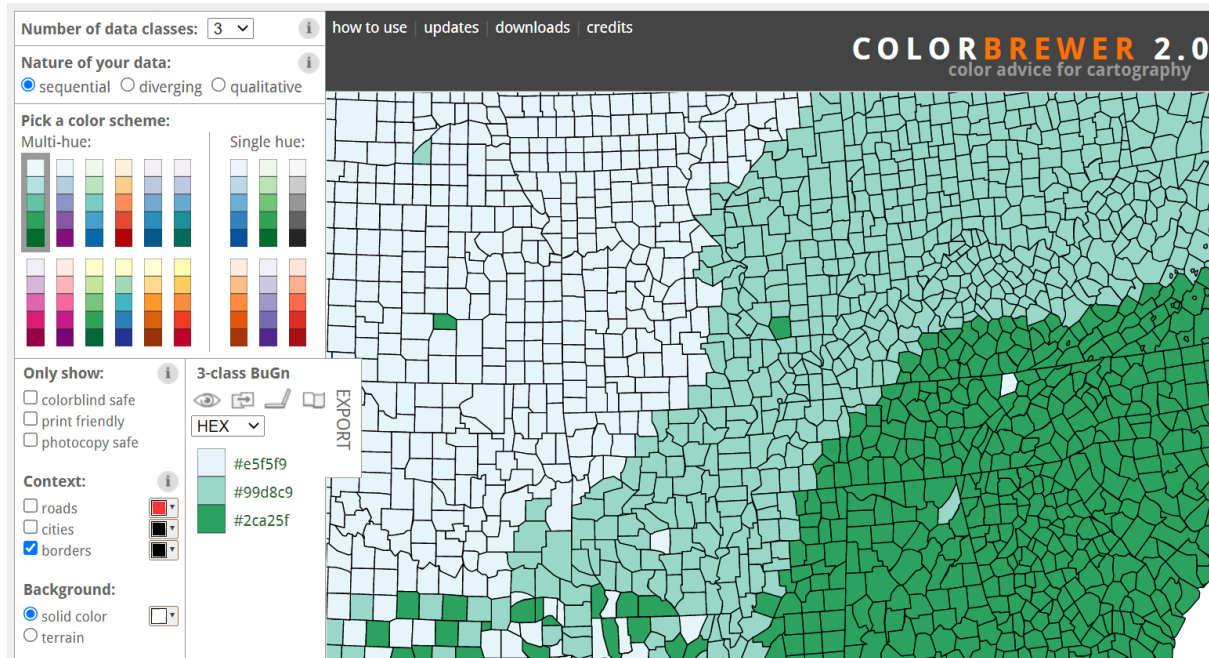
# This is not Carnival yet!

	Questions							
	Q1: Will the user realistically be trying to do this action?		Q2: Is the action visible?		Q3: Will user recognize the action as being the correct one?		Q4: Will the user understand the feedback/ is the feedback appropriate?	
	Yes	No	Yes	No	Yes	No	Yes	No
Task 1	5	1	6	0	4	2	3	3
Task 2	5	1	3	3	4	2	4	2
Task 3	4	2	5	1	5	1	6	0



# Use an appropriate color palette!

<https://colorbrewer2.org/>



	Questions							
	Q1: Will the user realistically be trying to do this action?		Q2: Is the action visible?		Q3: Will user recognize the action as being the correct one?		Q4: Will the user understand the feedback/ is the feedback appropriate?	
	Yes	No	Yes	No	Yes	No	Yes	No
Task 1	5	1	6	0	4	2	3	3
Task 2	5	1	3	3	4	2	4	2
Task 3	4	2	5	1	5	1	6	0

# Use an appropriate color palette!

<https://colorbrewer2.org/>

Pick « Sequential »  
as values are ordered

Pick 7 colors as table values go from 0 to 6

Activate  
« Color blind safe »

Number of data classes: 7

Nature of your data:  
 sequential  diverging  qualitative

Pick a color scheme:  
 Multi-hue:   Single hue:

Only show:  
 colorblind safe  
 print friendly  
 photocopy safe

Context:  
 roads  
 cities  
 borders

Background:  
 solid color  terrain

7-class PuBu  
 HEX  
 #f1ee66  
 #d0d1e6  
 #a6bddb  
 #74a9cf  
 #3690c0  
 #0570b0  
 #034e7b

	Questions							
	Q1: Will the user realistically be trying to do this action?		Q2: Is the action visible?		Q3: Will user recognize the action as being the correct one?		Q4: Will the user understand the feedback/ is the feedback appropriate?	
	Yes	No	Yes	No	Yes	No	Yes	No
Task 1	5	1	6	0	4	2	3	3
Task 2	5	1	3	3	4	2	4	2
Task 3	4	2	5	1	5	1	6	0

# Use an appropriate color palette!

<https://colorbrewer2.org/>

Pick 7 colors as table values go from 0 to 6

Pick « Sequential » as values are ordered

Activate « Color blind safe »

Number of data classes: 7

Nature of your data:  sequential  diverging  qualitative

Pick a color scheme:

Multi-hue:

Single hue:

Only show:  colorblind safe  print friendly  photocopy safe

Context:  roads  cities  borders

Background:  solid color  terrain

7-class PuBu

HEX

- #f1ee66
- #d0d1e6
- #a6bddb
- #74a9cf
- #3690c0
- #0570b0
- #034e7b

Apply colors on table

	Questions							
	Q1: Will the user realistically be trying to do this action?		Q2: Is the action visible?		Q3: Will user recognize the action as being the correct one?		Q4: Will the user understand the feedback/ is the feedback appropriate?	
	Yes	No	Yes	No	Yes	No	Yes	No
Task 1	5	1	6	0	4	2	3	3
Task 2	5	1	3	3	4	2	4	2
Task 3	4	2	5	1	5	1	6	0

# Use an appropriate color palette!

<https://colorbrewer2.org/>

Pick « Diverging »  
as values are binary



Activate  
« Color blind safe »



	Questions							
	Q1: Will the user realistically be trying to do this action?		Q2: Is the action visible?		Q3: Will user recognize the action as being the correct one?		Q4: Will the user understand the feedback/ is the feedback appropriate?	
	Yes	No	Yes	No	Yes	No	Yes	No
Task 1	5	1	6	0	4	2	3	3
Task 2	5	1	3	3	4	2	4	2
Task 3	4	2	5	1	5	1	6	0

# Use an appropriate color palette!

<https://colorbrewer2.org/>

Pick « Qualitative »  
as values are  
categorical



Activate  
« Color blind safe »

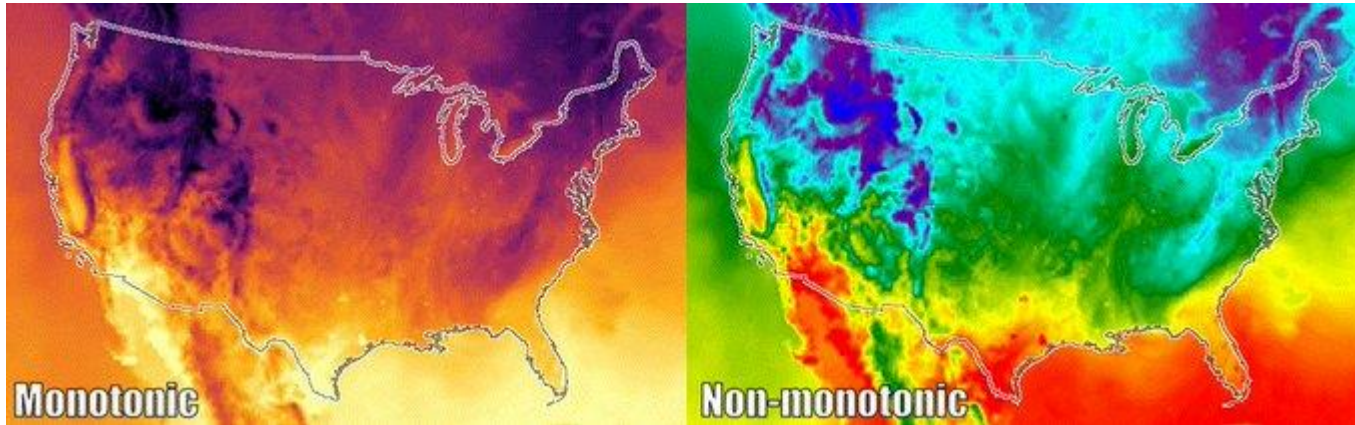


	Questions							
	Q1: Will the user realistically be trying to do this action?		Q2: Is the action visible?		Q3: Will user recognize the action as being the correct one?		Q4: Will the user understand the feedback / is the feedback appropriate?	
	Yes	No	Yes	No	Yes	No	Yes	No
Task 1	5	1	6	0	4	2	3	3
Task 2	5	1	3	3	4	2	4	2
Task 3	4	2	5	1	5	1	6	0

# Use an appropriate color palette!

	Questions							
	Q1: Will the user realistically be trying to do this action?		Q2: Is the action visible?		Q3: Will user recognize the action as being the correct one?		Q4: Will the user understand the feedback/ is the feedback appropriate?	
	Yes	No	Yes	No	Yes	No	Yes	No
Task 1	5	1	6	0	4	2	3	3
Task 2	5	1	3	3	4	2	4	2
Task 3	4	2	5	1	5	1	6	0

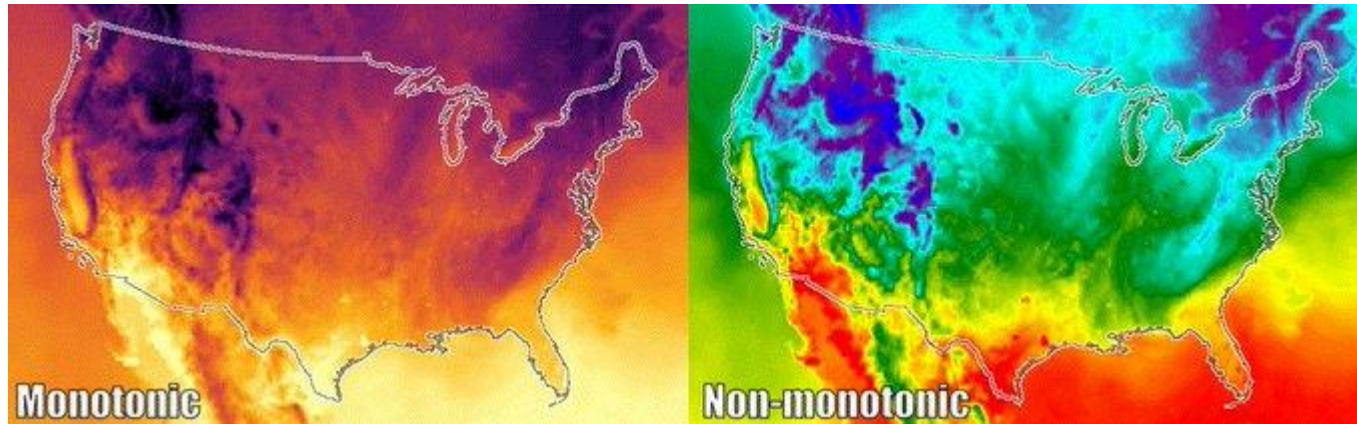
# Use an appropriate color palette!



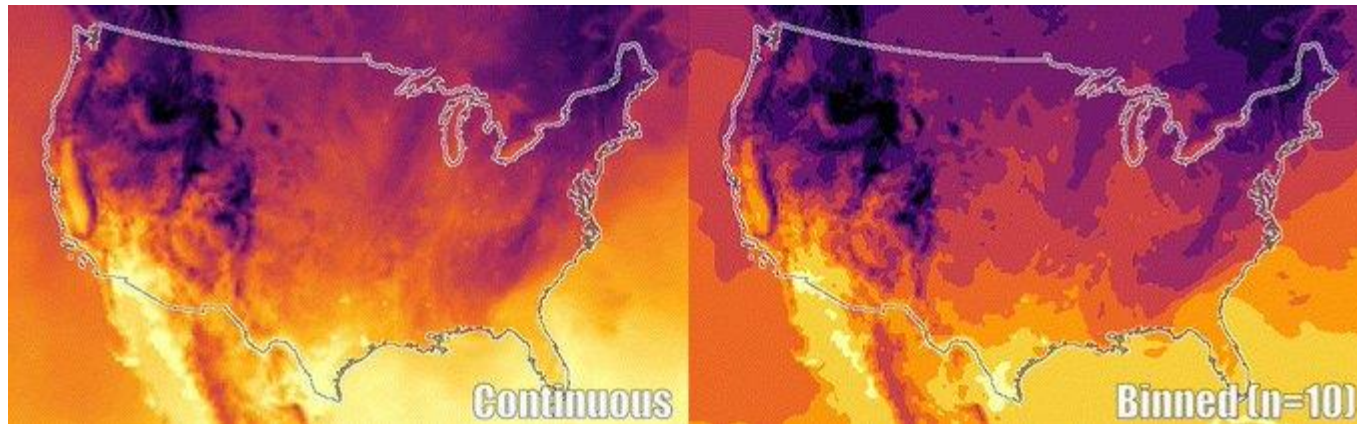
<https://twitter.com/i/status/1210631357317074944>



# Use an appropriate color palette!



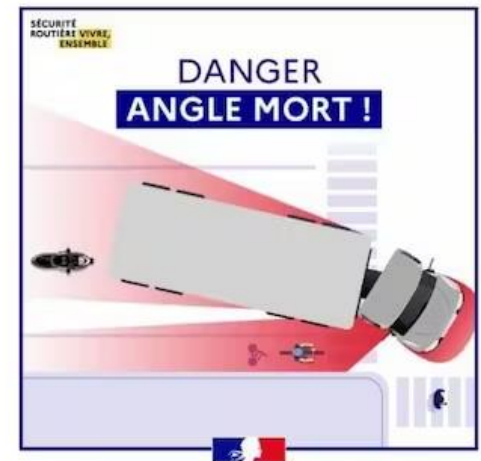
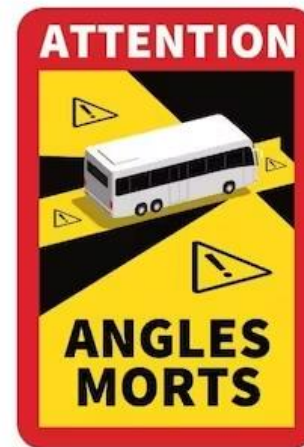
<https://twitter.com/i/status/1210631357317074944>



<https://twitter.com/i/status/1211382829277253632>

Michael Aupetit - QCRI

# Re-design example



# Re-design example



# Gestalt theory of Visual Perception

- The **Gestalt theory**, established in [\(Koffka 1935\)](#), explains the main principles that lead to images interpretation.
- [\(Ware 2004\)](#) summarizes them as follows:

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law of similarity

*Similar elements tend to be perceptually grouped together*

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law of proximity

*Things that are close together are perceptually grouped together*

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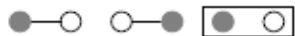
law of similarity

*Similar elements tend to be perceptually grouped together*



law of proximity

*Things that are close together are perceptually grouped together*



law of connectedness

*Things that are close together are perceptually grouped together*

# Gestalt theory of Visual Perception

- The **Gestalt theory**, established in [\(Koffka 1935\)](#), explains the main principles that lead to images interpretation.
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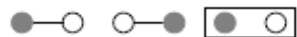
law of similarity

*Similar elements tend to be perceptually grouped together*



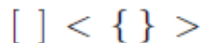
law of proximity

*Things that are close together are perceptually grouped together*



law of connectedness

*Things that are close together are perceptually grouped together*



law of symmetry

*Two symmetrically arranged visual elements tend to be perceived as a whole*



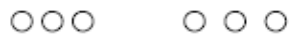
# Gestalt theory of Visual Perception

- The **Gestalt theory**, established in [\(Koffka 1935\)](#), explains the main principles that lead to images interpretation.
- [\(Ware 2004\)](#) summarizes them as follows:



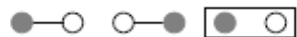
law of similarity

*Similar elements tend to be perceptually grouped together*



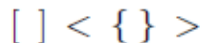
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*A closed contour tends to be seen as a single object*

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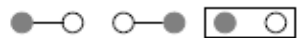
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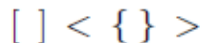
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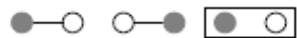
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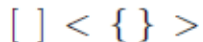
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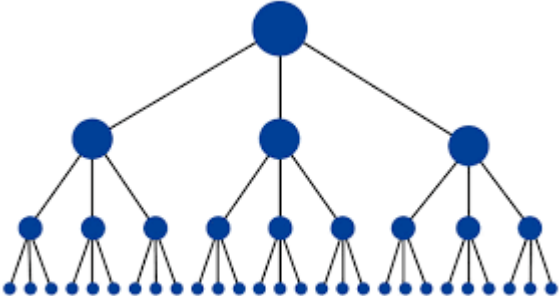
law of figure and ground *When a part is seen as an object the other parts are seen as background*

# Design Principles are based on Gestalt Theory

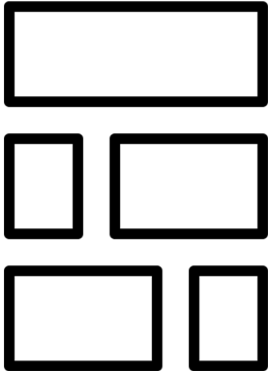
Simplification

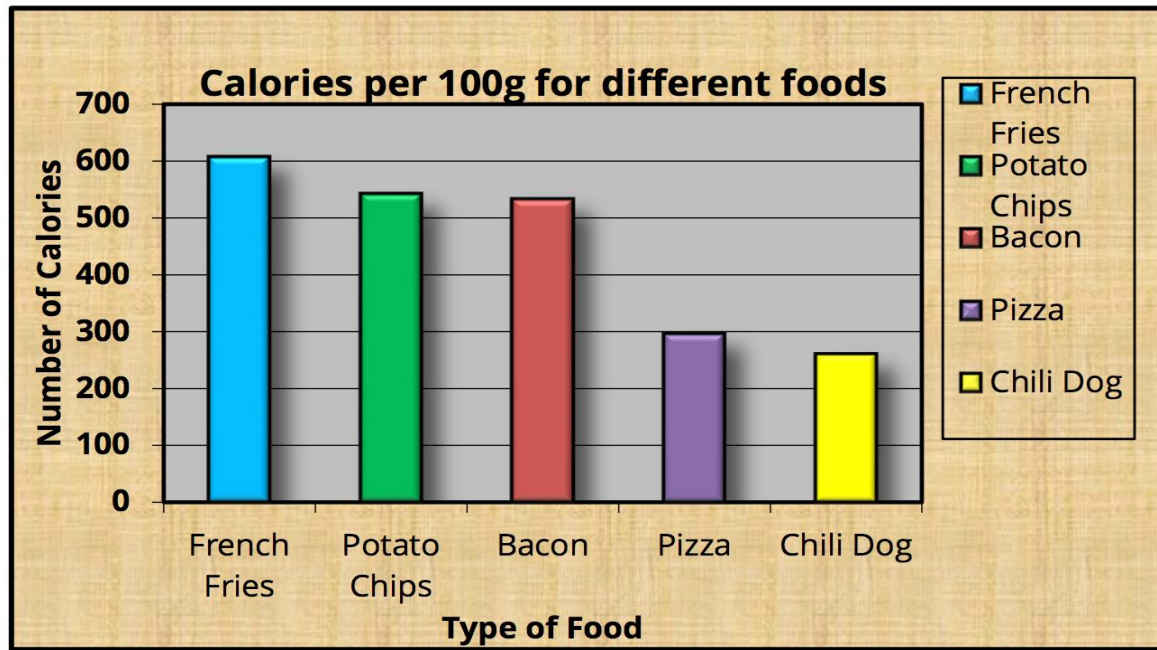


Hierarchy

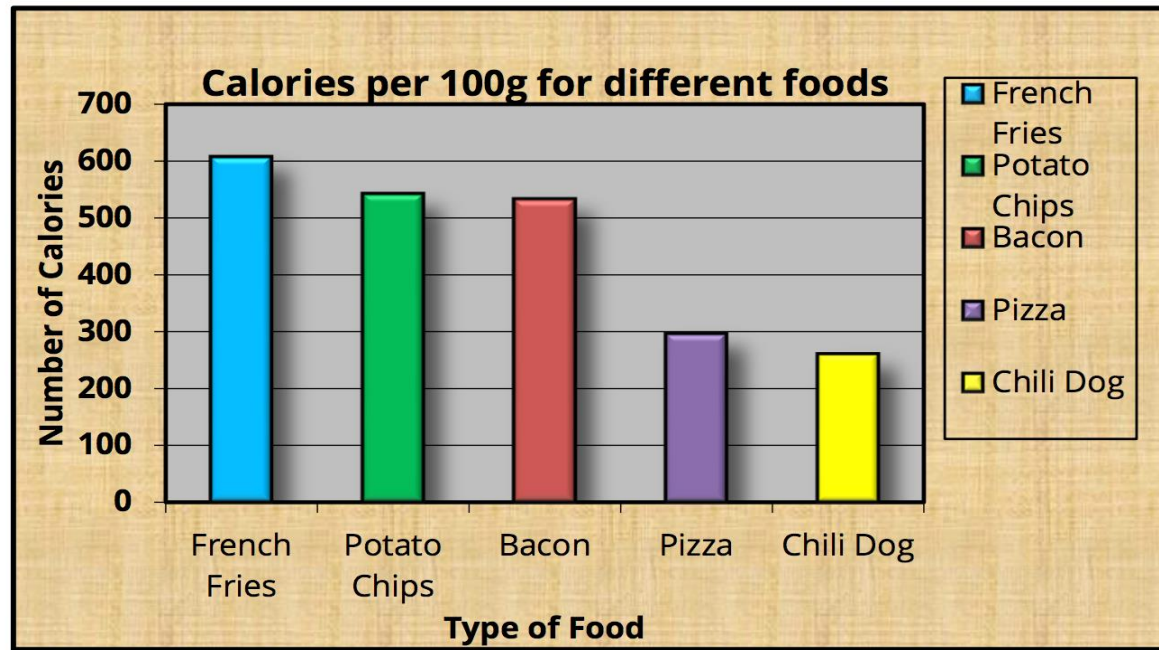


Layout



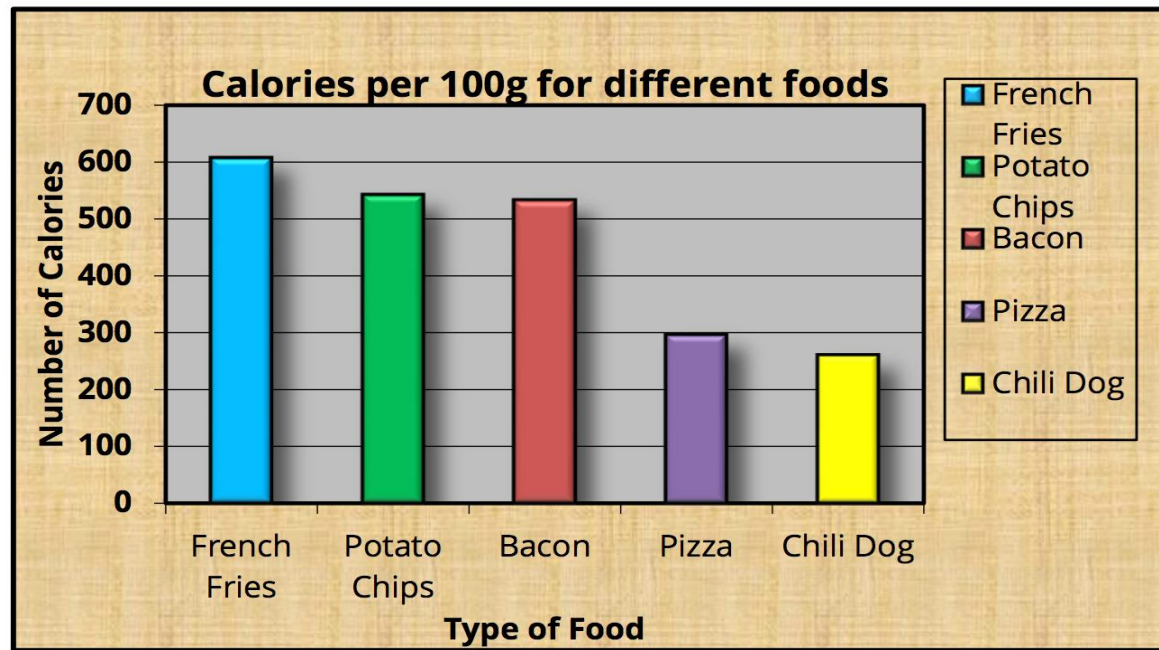


Simplification



Simplification

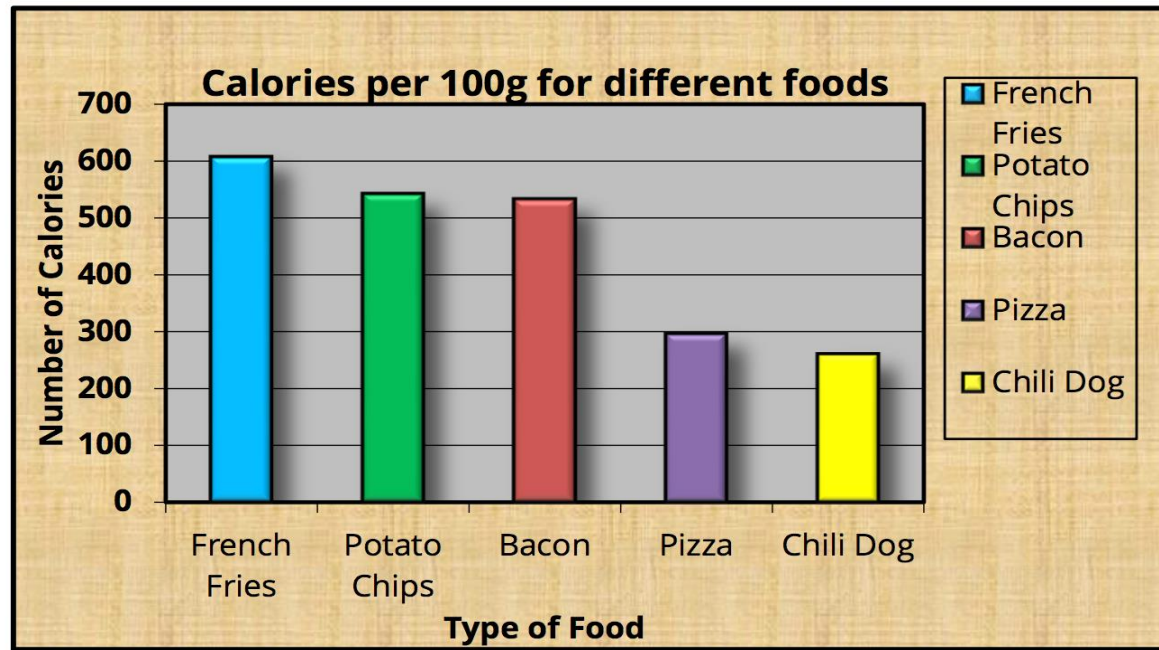
What is the problem with this graphic?



Simplification

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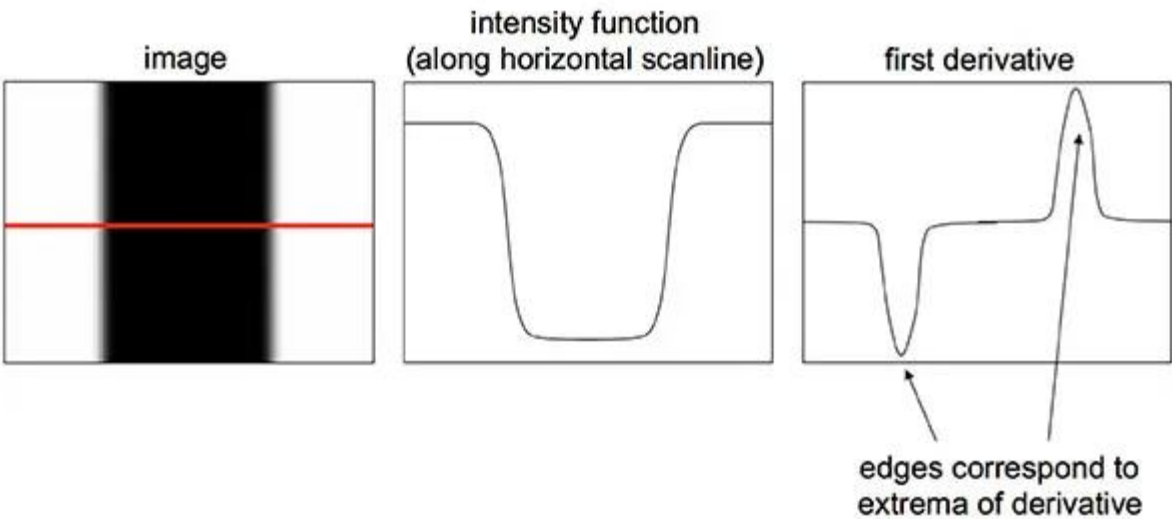




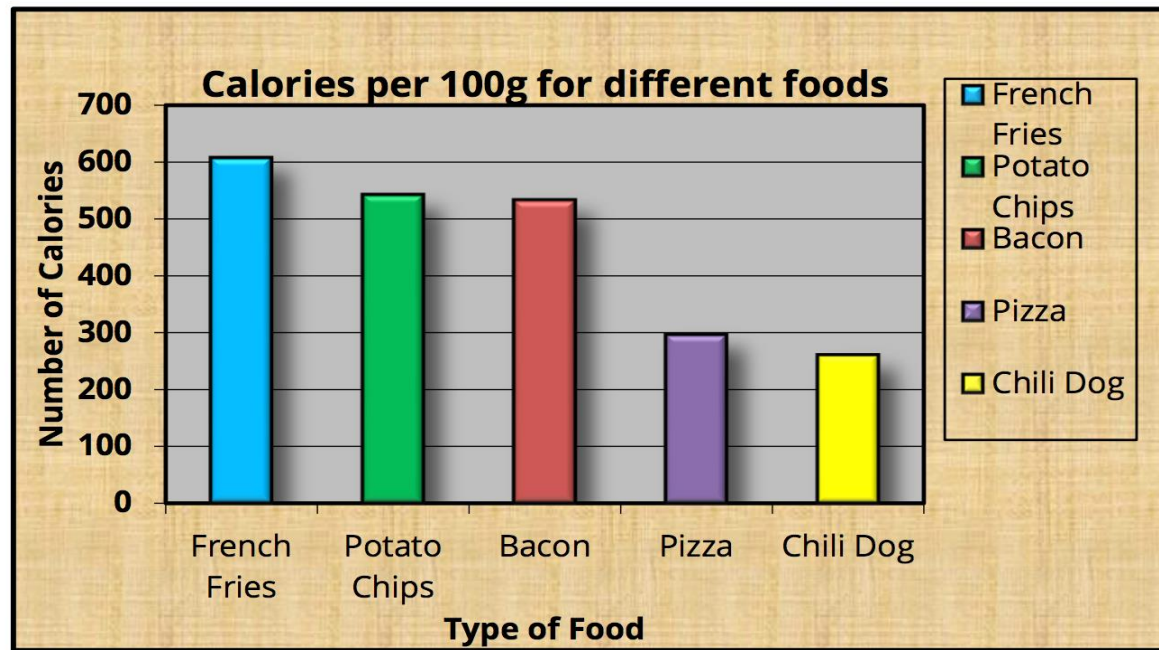
# Simplification

What is the problem with this graphic?

Edges are like hurdles  
They catch attention,  
raise question about  
their meaning wrt data

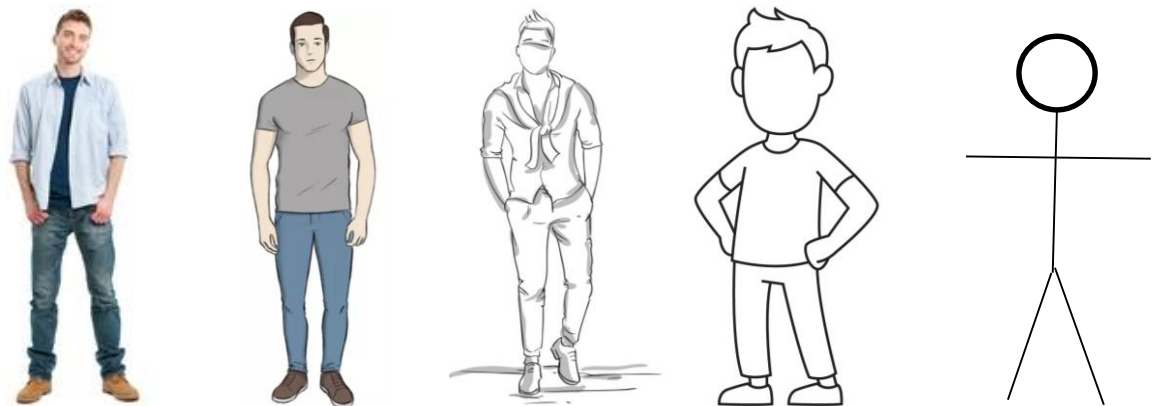




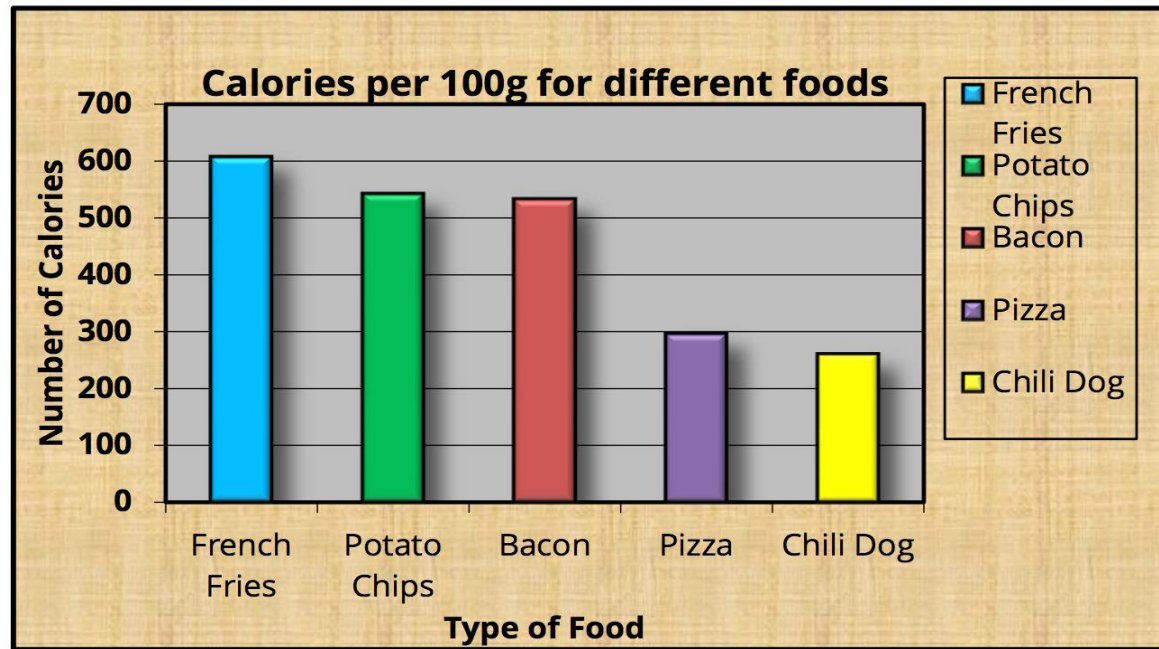


## Simplification

What is the problem with this graphic?



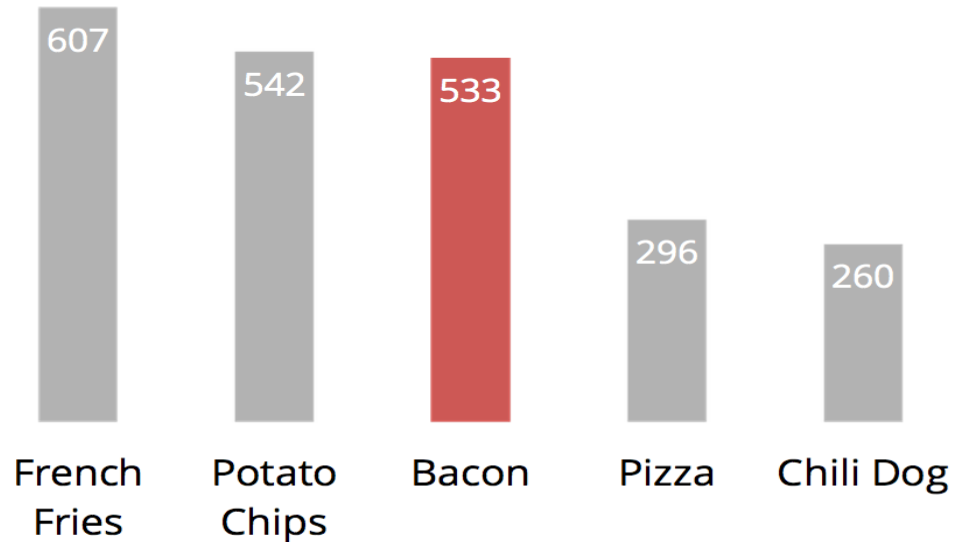
Do we really need all these details?  
Texture? Colors? Shadows? 3D effects?



Simplification

Data... only data!

Calories per 100g



Consistency\*

\*sorry, my slides are not consistent!

Change in **graphics** are explained  
as change in **data**

Consistency\*

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Change in **graphics** are explained  
as change in **data**

Consistency\*

Change in **style** are explained  
as change in **meaning**

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Change in **graphics** are explained  
as change in **data**

Consistency\*

Change in **style** are explained  
as change in **meaning**

Establish a **style** for each element in a design  
...and use it on similar elements

\*sorry, my slides are not consistent!

Visual hierarchy

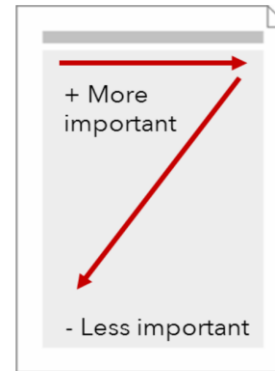
# Visual hierarchy

Most **prominent**  
is perceived as  
most **important**



## Position

Eye flow – “Z” path



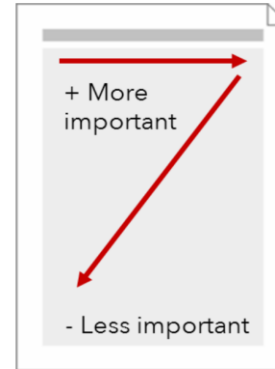
In Western world only!  
In Arabic regions  
it starts from top right!

## Visual hierarchy

Most **prominent**  
is perceived as  
most **important**

Eye flow – “Z” path

Position



In Western world only!  
In Arabic regions  
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Visual hierarchy

Size

Heading 1

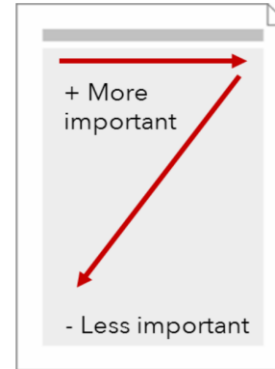
Heading 2

Heading 3



Most **prominent**  
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most **important**

Eye flow – “Z” path



In Western world only!  
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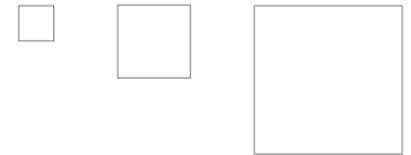
Position

Size

Heading 1

Heading 2

Heading 3



Most **prominent**  
is perceived as  
most **important**

Contrast

Heading 1

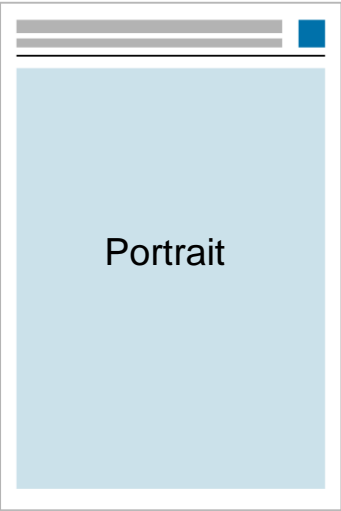
Heading 2

Heading 3



Visual hierarchy

# Publication



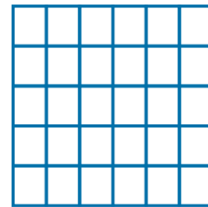
# Presentation



Layout

The baseline grid provides a guide for positioning elements on the page with accuracy, which is difficult to achieve by eye alone

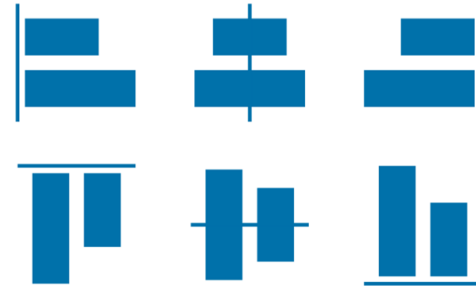
Grid





Makes your design visually more appealing and helps to create relationships between elements

## Alignment





Related elements should be placed closed  
Unrelated elements should not be placed closed

## Proximity





Find a good balance, not too cluttered nor  
too much empty space

Space



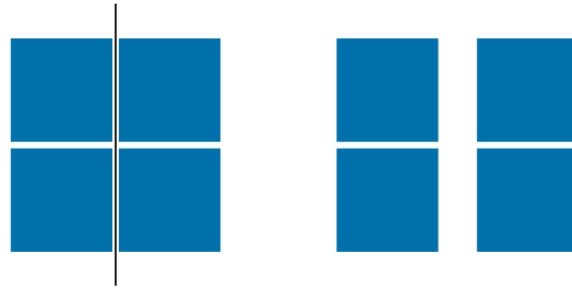
Find a good balance, not too cluttered nor  
too much empty space

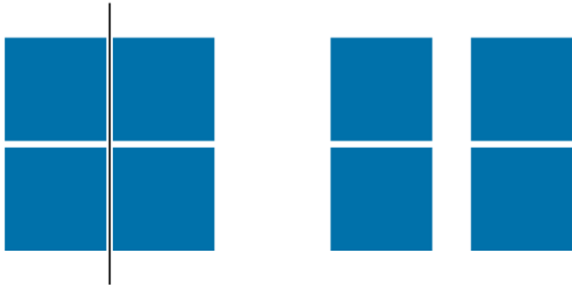
Space



Lines or space

Separation





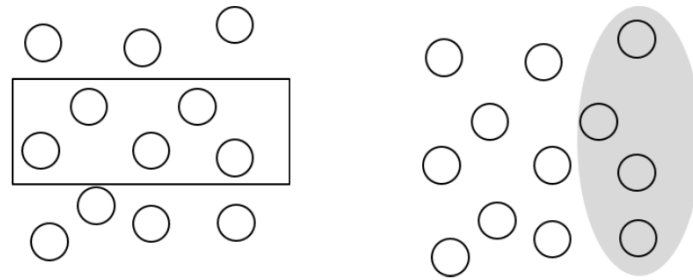
# Separation

A treemap



Eyes perceive objects as belonging together when they are enclosed

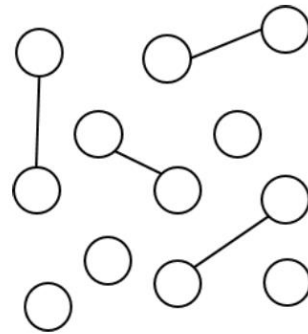
## Enclosure

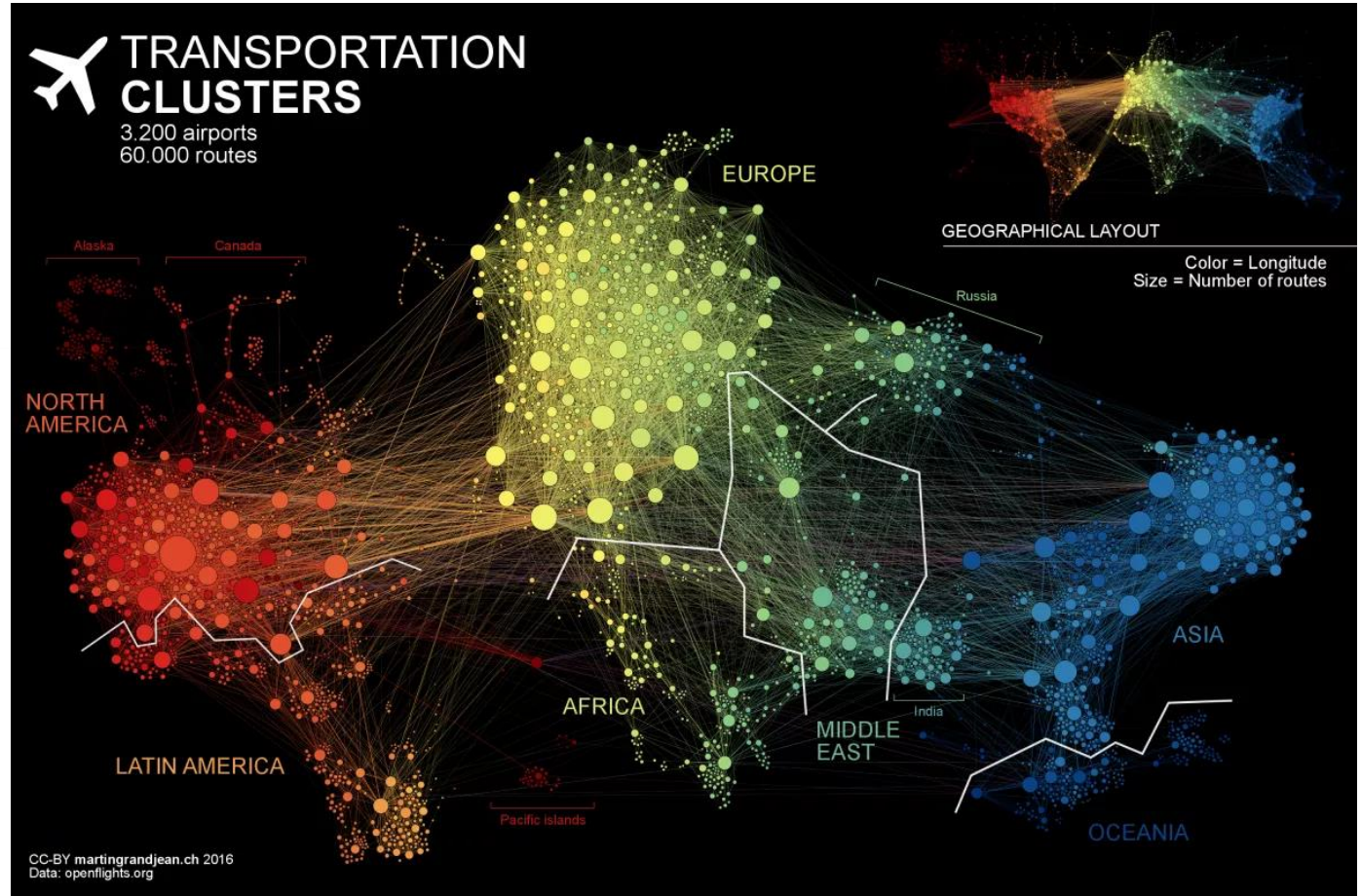
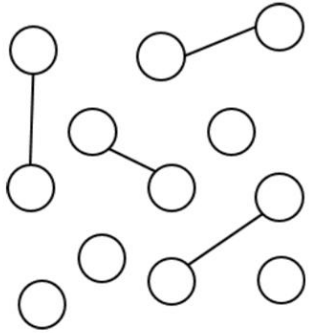




Eyes perceive objects as belonging together when they are connected

Connection



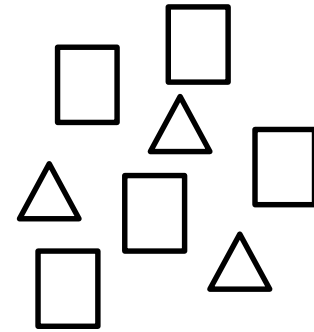
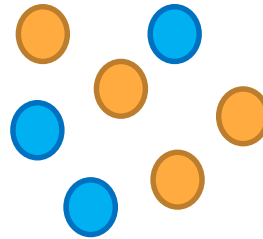


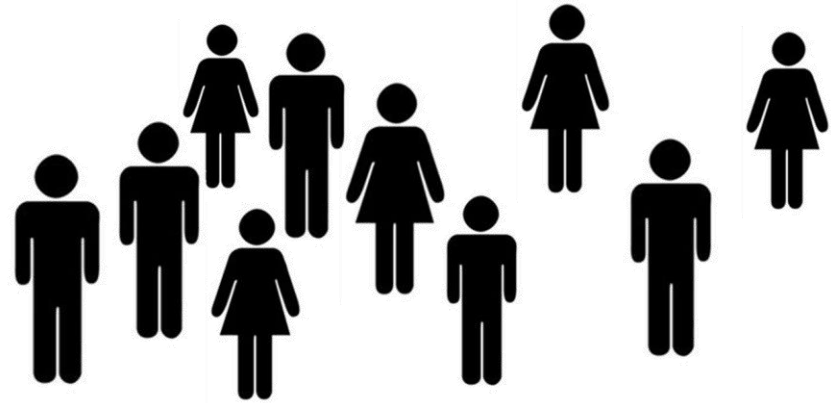
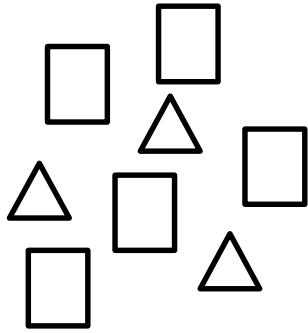
Connection



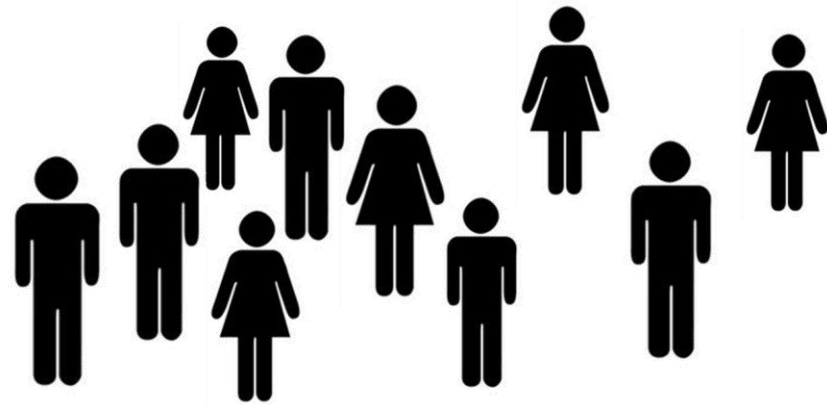
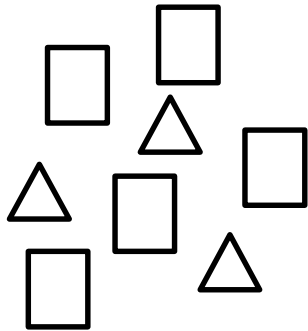
Eyes perceive objects as belonging together when they are similar (color, shape...)

Similarity

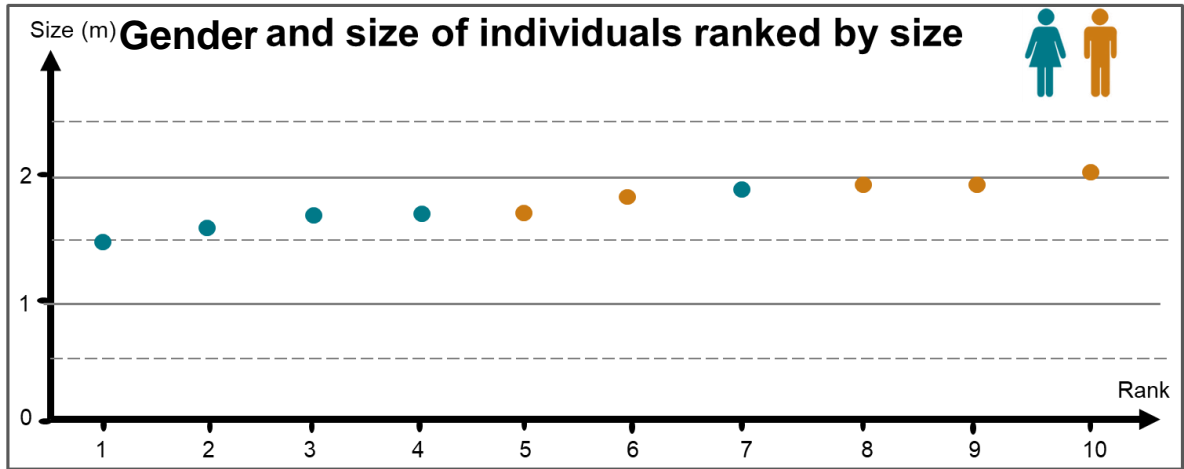
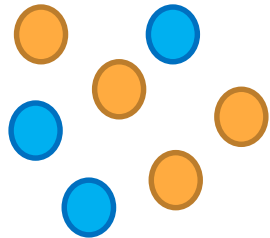




Similarity



# Similarity



**DataViz** = Tidy up to **optimize task completion...**

Before



**DataViz** = Tidy up to **optimize task completion...**

Before



After



# DataViz = Tidy up to optimize task completion...

## Before

What is the **purpose** of this graphic?

Can you determine the **key messages**?

Depuis le début de la crise et à cause du conflit au nord, environ **412 401** personnes ont été forcées de fuir le nord du pays. Parmi ces personnes **203 843** sont des déplacés internes et **208 558** sont des réfugiés dans les pays voisins. Environ **5,01 millions** de personnes sont affectées par la crise complexe au Mali, y compris **4,6 millions** de personnes à risque d'insécurité alimentaire. Les pénuries de nourriture et les mouvements de population internes ont eu des conséquences importantes sur la capacité de résilience des populations.

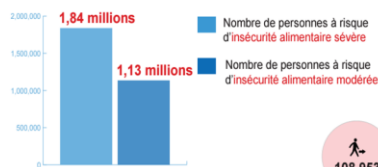
### Réponse Humanitaire

Nombre de personnes assistées par Cluster

- 400 389
- 2 525 628
- 105 644
- 269 103
- 1 144 239
- 840 000

### Sécurité Alimentaire

4,6 millions de personnes restent estimées à risque d'insécurité alimentaire  
2,97 millions de personnes affectées par la sécheresse vivant au Sud  
1,63 millions de personnes affectées par le conflit vivant au Nord



210 communes affectées par une insécurité alimentaire sévère  
> 56 communes vivent de difficultés économiques provoquant une insécurité alimentaire modérée

### Crise Nutritionnelle

560 000 enfants de moins de 5 ans sont en risque de malnutrition aiguë, dont 175 000 en malnutrition aiguë sévère et 385 000 en malnutrition aiguë modérée.

### Les Violations des Droits de l'Homme au Nord

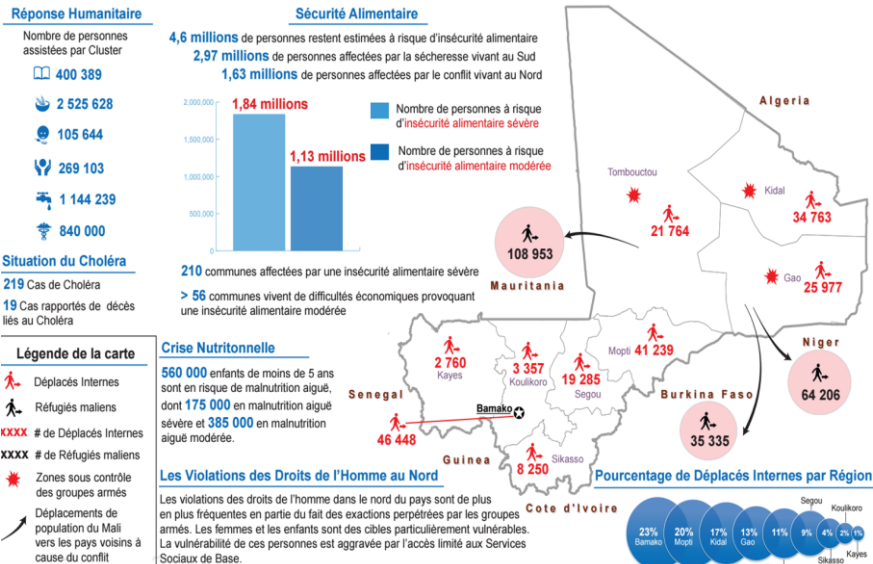
Les violations des droits de l'homme dans le nord du pays sont de plus en plus fréquentes en partie du fait des exactions perpétrées par les groupes armés. Les femmes et les enfants sont des cibles particulièrement vulnérables. La vulnérabilité de ces personnes est aggravée par l'accès limité aux Services Sociaux de Base.

### Situation du Choléra

219 Cas de Choléra  
19 Cas rapportés de décès liés au Choléra

### Légende de la carte

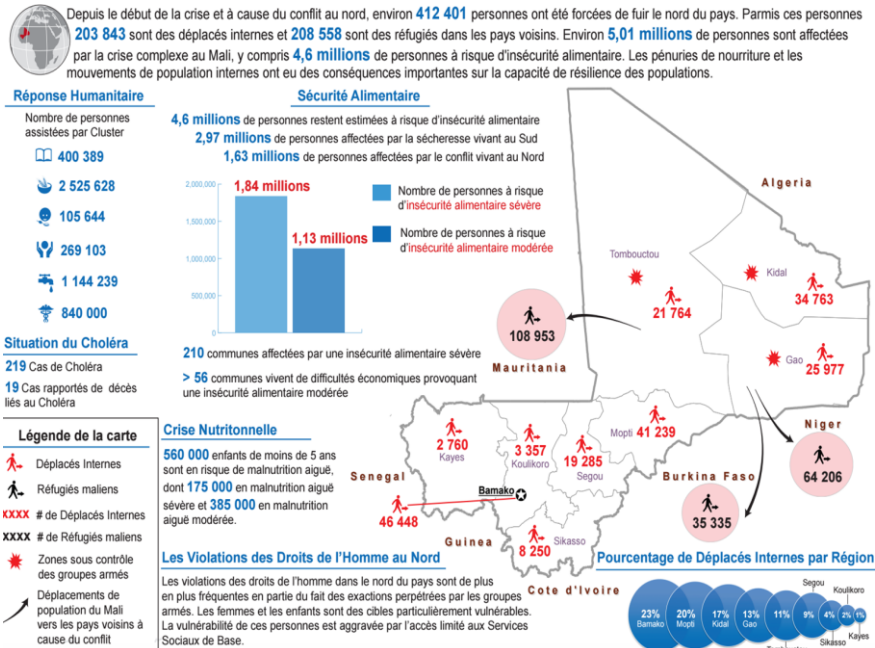
- Déplacés Internes
- Réfugiés maliens
- XXXX # de Déplacés Internes
- XXXX # de Réfugiés maliens
- Zones sous contrôle des groupes armés
- Déplacements de population du Mali vers les pays voisins à cause du conflit



# DataViz = Tidy up to optimize task completion...

## Before

What is the **purpose** of this graphic?  
 Can you determine the **key messages**?

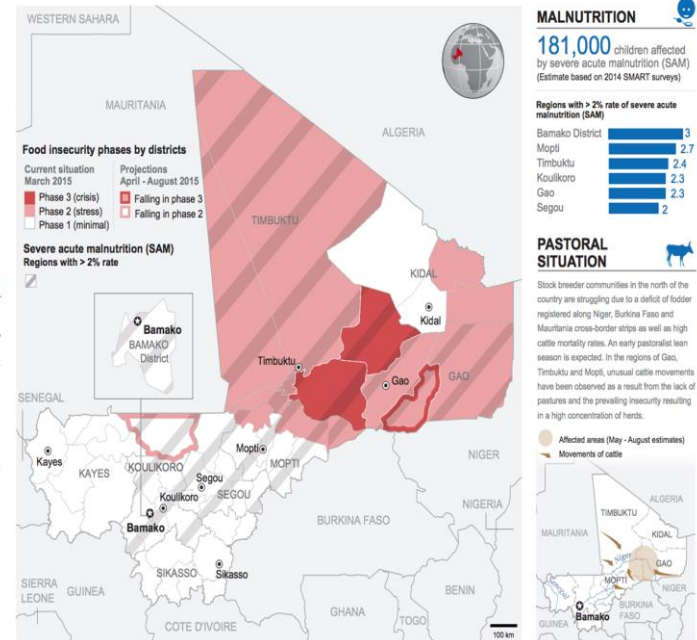
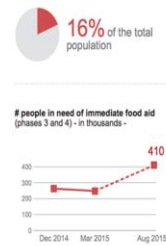


## After

Show **more clear lines** and the story.  
 Much **easier to understand** the key points.  
 Such communications **help decision makers**.

Food security and malnutrition remain major concerns in Mali. During the lean season (June - August), i.e. before the next harvests when grain stocks are depleted, it is estimated that nearly one out of every six households will need support for their livelihood. Among them, 410,000 people will require immediate food assistance. Countrywide, one out of every eight children suffers from malnutrition; including 181,000 who are affected by the most severe form and face a nine-fold mortality risk.

**FOOD SECURITY**  
 2.5 million people affected by moderate and severe food insecurity (as of 31 March 2015)







# Example: searching for a flight

# Example: searching for a flight

Opodo

Retour
  Aller simple  
 multi-destinations

Classe  
 Economique

Compagnie aérienne  
 sans préférence

**Rechercher**

Filter les résultats

PRIX (PAR PERSONNE) ? -



HORAIRES DES VOLS ? -

Voyage aller

- Décollage
- Atterrissage



Voyage retour

- Décollage
- Atterrissage



Total TTC (taxes incluses)\*: 559,34 € Tarif par adulte: **558,34 €**

**Aller** : jeu. 12 juin 14

Départ	Arrivée	Durée	Disponibilité	Compagnie
11:00 Paris Charles de Gaulle Apt, France	17:59 New York La Guardia Apt, États-Unis	1 escale(s) 12:59	bonne	US Airways
11:15 Paris Charles de Gaulle Apt, France	16:30 New York La Guardia Apt, États-Unis	1 escale(s) 11:15	siège(s) 3	US Airways
11:15 Paris Charles de Gaulle Apt, France	16:45 Newark Liberty International Apt, États-Unis	1 escale(s) 11:30	bonne	US Airways

**Retour** : jeu. 19 juin 14

Départ	Arrivée	Durée	Disponibilité	Compagnie
07:59 New York La Guardia Apt, États-Unis	06:55 + 1 jour(s) Paris Charles de Gaulle Apt, France	1 escale(s) 16:56	bonne	US Airways
08:10 Newark Liberty International Apt, États-Unis	06:55 + 1 jour(s) Paris Charles de Gaulle Apt, France	1 escale(s) 16:45	siège(s) 5	US Airways
08:20 New York J F Kennedy International Apt, États-Unis	06:55 + 1 jour(s) Paris Charles de Gaulle Apt, France	1 escale(s) 16:35	bonne	US Airways

Avec la carte Opodo, payez ce vol en plusieurs fois. Plus d'infos.

**Sélectionner**

Total TTC (taxes incluses)\*: 559,44 € Tarif par adulte: **559,44 €**

**Aller** : jeu. 12 juin 14

Départ	Arrivée	Durée	Disponibilité	Compagnie
11:15 Paris Charles de Gaulle Apt, France	16:30 New York La Guardia Apt, États-Unis	1 escale(s) 11:15	siège(s) 3	US Airways

# Example: searching for a flight

**Symbolic** encoding (arbitrary convention)

Numbers and letters

Opodo

Retour  Aller simple  
 multi-destinations

Classe  
Economique

Compagnie aérienne  
sans préférence

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# Example: searching for a flight

## Symbolic encoding (arbitrary convention)

Numbers and letters

**Very precise** values but  
**Hard to find** useful numbers  
Need scanning

## Opodo

Retour  Aller simple  
 multi-destinations

Classe  
Economique

Compagnie aérienne  
sans préférence

**Rechercher**

**Filter les résultats**

**PRIX (PAR PERSONNE)** ? -

De 558 EUR À 3,721 EUR

**HORAIRES DES VOLS** ? -

**Voyage aller**

- Décollage
- Atterrissage

De 06h25 à 21h50

**Voyage retour**

- Décollage
- Atterrissage

De 07h15 à 23h55

Total TTC (taxes incluses)\*: 559,34 € Tarif par adulte: **558,34 €**

**Aller** : jeu. 12 juin 14

Départ	Arrivée	Durée	Disponibilité	Compagnie
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**Sélectionner**

Total TTC (taxes incluses)\*: 559,44 € Tarif par adulte: **559,44 €**

**Aller** : jeu. 12 juin 14

Départ	Arrivée	Durée	Disponibilité	Compagnie
11:15 Paris Charles de Gaulle Apt, France	16:30 New York La Guardia Apt, États-Unis	1 escale(s) 11:15	siège(s) 3	US Airways

# Example: searching for a flight

Symbolic encoding (arbitrary convention)

Numbers and letters

Very precise values but  
Hard to find useful numbers  
Need scanning

## Opodo

Retour  Aller simple   
multi-destinations

Classe  
Economique

Compagnie aérienne  
sans préférence

Rechercher

Filter les résultats

PRIX (PAR PERSONNE) ? -

De 588 EUR À 3,721 EUR

HORAIRES DES VOLS ? -

Voyage aller

Décollage  
 Atterrissage

De 06h25 à 21h50

Voyage retour

Décollage  
 Atterrissage

De 07h15 à 23h55

Total TTC (taxes incluses)\*: 559,34 € Tarif par adulte: 558,34 €

aller : jeu. 12 juin 14

Départ	Arrivée	Durée	Disponibilité	Compagnie
11:00 Paris Charles de Gaulle Apt, France	17:59 New York La Guardia Apt, États-Unis	1 escale(s) 12:59	bonne	US Airways
11:15 Paris Charles de Gaulle Apt, France	16:30 New York La Guardia Apt, États-Unis	1 escale(s) 11:15	siège(s) 3	US Airways
11:15 Paris Charles de Gaulle Apt, France	16:45 Newark Liberty International Apt, États-Unis	1 escale(s) 11:30	bonne	US Airways

Retour : jeu. 19 juin 14

Départ	Arrivée	Durée	Disponibilité	Compagnie
07:59 New York La Guardia Apt, États-Unis	06:55 + 1 jour(s) Paris Charles de Gaulle Apt, France	1 escale(s) 16:56	bonne	US Airways
08:10 Newark Liberty International Apt, États-Unis	06:55 + 1 jour(s) Paris Charles de Gaulle Apt, France	1 escale(s) 16:45	siège(s) 5	US Airways
08:20 New York J F Kennedy International Apt, États-Unis	06:55 + 1 jour(s) Paris Charles de Gaulle Apt, France	1 escale(s) 16:35	bonne	US Airways

Avec la carte Opodo, payez ce vol en plusieurs fois. Plus d'infos.

Sélectionner

Total TTC (taxes incluses)\*: 559,44 € Tarif par adulte: 559,44 €

aller : jeu. 12 juin 14

Départ	Arrivée	Durée	Disponibilité	Compagnie
11:15 Paris Charles de Gaulle Apt, France	16:30 New York La Guardia Apt, États-Unis	1 escale(s) 11:15	siège(s) 3	US Airways

## Hipmunk

Get Fare Alert  Sort by: Agony Price Duration Departure Arrival Filter by: Airlines Airports Stops Only Nonstops

Roundtrip price / person (includes taxes & fees)

Additional baggage fees may apply

	depart	3am	noon	6am	9am	6pm	9pm	midn	3am	arrive
Select Leg \$775 roundtrip	ORY → EWR					British				8h 35m nonstop
Select Leg \$930 roundtrip	ORY → JFK			LHR		British				10h 00m 1 stop
Select Leg \$930 roundtrip	ORY → JFK			LHR		British				10h 10m 1 stop
Select Leg \$930 roundtrip	ORY → EWR			LHR		British				11h 00m 1 stop
Select Leg \$930 roundtrip	ORY → JFK			LHR		American*				11h 00m 1 stop
Select Leg \$930 roundtrip	ORY → JFK					LHR				11h 00m 1 stop
Select Leg \$930 roundtrip	ORY → EWR					LHR				11h 20m 1 stop
Select Leg \$931 roundtrip	CDG → JFK			LHR		British				10h 55m 1 stop
Select Leg \$931 roundtrip	CDG → JFK					LHR				10h 55m 1 stop

Chat with

# Example: searching for a flight

**Symbolic** encoding (arbitrary convention)

Numbers and letters

**Analogic** encoding (sensory)

Drawings, shapes, colors

**Very precise** values but  
**Hard to find** useful numbers  
 Need scanning

## Opodo

**Opodo**

Retour  Aller simple   
 multi-destinations

Classe: Economique

Compagnie aérienne: sans préférence

**Rechercher**

**Filter les résultats**

**PRIX (PAR PERSONNE)** De 558 EUR À 3,721 EUR

**HORAIRES DES VOLS** De 06h25 à 21h50

**Voyage aller**  
 Décollage  
 Atterrissage

**Voyage retour**  
 Décollage  
 Atterrissage

De 07h15 à 23h55

Total TTC (taxes incluses)\*: 558,34 € Tarif par adulte: **558,34 €**

**Aller** : jeu. 12 juin 14

Départ	Arrivée	Durée	Disponibilité	Compagnie
11:00 Paris Charles de Gaulle Apt, France	17:59 New York La Guardia Apt, États-Unis	1 escale(s) 12:59	bonne	US Airways
11:15 Paris Charles de Gaulle Apt, France	16:30 New York La Guardia Apt, États-Unis	1 escale(s) 11:15	siège(s) 3	US Airways
11:15 Paris Charles de Gaulle Apt, France	16:45 Newark Liberty International Apt, États-Unis	1 escale(s) 11:30	bonne	US Airways

**Retour** : jeu. 19 juin 14

Départ	Arrivée	Durée	Disponibilité	Compagnie
07:59 New York La Guardia Apt, États-Unis	06:55 Paris Charles de Gaulle Apt, France	1 escale(s) 16:56	bonne	US Airways
08:10 Newark Liberty International Apt, États-Unis	06:55 Paris Charles de Gaulle Apt, France	1 escale(s) 16:45	siège(s) 5	US Airways
08:20 New York J F Kennedy International Apt, États-Unis	06:55 Paris Charles de Gaulle Apt, France	1 escale(s) 16:35	bonne	US Airways

Avec la carte Opodo, payez ce vol en plusieurs fois. Plus d'infos.

**Sélectionner**

Total TTC (taxes incluses)\*: 559,44 € Tarif par adulte: **559,44 €**

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11:15 Paris Charles de Gaulle Apt, France	16:30 New York La Guardia Apt, États-Unis	1 escale(s) 11:15	siège(s) 3	US Airways

## Hipmunk

**Hipmunk**

Get Fare Alert | Sort by: Agony | Price | Duration | Departure | Arrival | Filter by: Airlines | Airports | Stops | Only Nonstops

Roundtrip price / person (includes taxes & fees)  
 Additional baggage fees may apply

	depart	3am	noon	3pm	6pm	9pm	midn	3am	arrive
Select Leg \$775 roundtrip	ORY → EWR				British				8h 35m nonstop
Select Leg \$930 roundtrip	ORY → JFK		LHR		British				10h 00m 1 stop
Select Leg \$930 roundtrip	ORY → JFK		LHR		British				10h 10m 1 stop
Select Leg \$930 roundtrip	ORY → EWR		LHR		British				11h 00m 1 stop
Select Leg \$930 roundtrip	ORY → JFK		LHR		American*				11h 00m 1 stop
Select Leg \$930 roundtrip	ORY → JFK				LHR				11h 00m 1 stop
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Select Leg \$931 roundtrip	CDG → JFK		LHR		British				10h 55m 1 stop
Select Leg \$931 roundtrip	CDG → JFK				LHR				10h 55m 1 stop

Chat with us

# Example: searching for a flight

**Symbolic** encoding (arbitrary convention)

Numbers and letters

**Very precise** values but  
**Hard to find** useful numbers  
 Need scanning

**Analogic** encoding (sensory)

Drawings, shapes, colors

**Less precise** values at first glance but available on demand  
**Easy to compare** flight/transit duration,  
 start/end local time, (un)direct flight, company name...

## Opodo

**Total TTC (taxes incluses)\*: 558,34 €** Tarif par adulte: **558,34 €**

**Aller : jeu. 12 juin 14**

Départ	Arrivée	Durée	Disponibilité	Compagnie
11:00 Paris Charles de Gaulle Apt, France	17:59 New York La Guardia Apt, États-Unis	1 escale(s) 12:59	bonne	US Airways
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**Retour : jeu. 19 juin 14**

Départ	Arrivée	Durée	Disponibilité	Compagnie
07:59 New York La Guardia Apt, États-Unis	06:55 + 1 jour(s) Paris Charles de Gaulle Apt, France	1 escale(s) 16:56	bonne	US Airways
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**Aller : jeu. 12 juin 14**

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## Hipmunk

**Roundtrip price / person (includes taxes & fees)**

Additional baggage fees may apply

Price	Route	Airline	Visual	Duration
\$775 roundtrip	ORY → EWR	British	[Visual: British Airways logo]	8h 35m nonstop
\$930 roundtrip	ORY → JFK	British	[Visual: British Airways logo]	10h 00m 1 stop
\$930 roundtrip	ORY → JFK	British	[Visual: British Airways logo]	10h 10m 1 stop
\$930 roundtrip	ORY → EWR	British	[Visual: British Airways logo]	11h 00m 1 stop
\$930 roundtrip	ORY → JFK	Multiple Airlines	[Visual: American logo]	11h 00m 1 stop
\$930 roundtrip	ORY → JFK	British	[Visual: British Airways logo]	11h 00m 1 stop
\$930 roundtrip	ORY → EWR	British	[Visual: British Airways logo]	11h 20m 1 stop
\$931 roundtrip	CDG → JFK	British	[Visual: British Airways logo]	10h 55m 1 stop
\$931 roundtrip	CDG → JFK	British	[Visual: British Airways logo]	10h 55m 1 stop

# Preattentive Processing

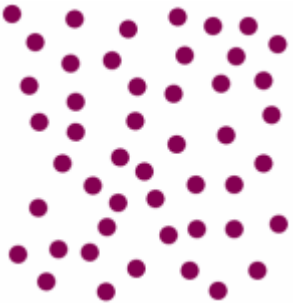
- **Instantaneous** detection of outlying elements with no cognitive effort ([Wong 2010](#))

<http://www.infovis.net/printMag.php?num=179&lang=2>



# Preattentive Processing

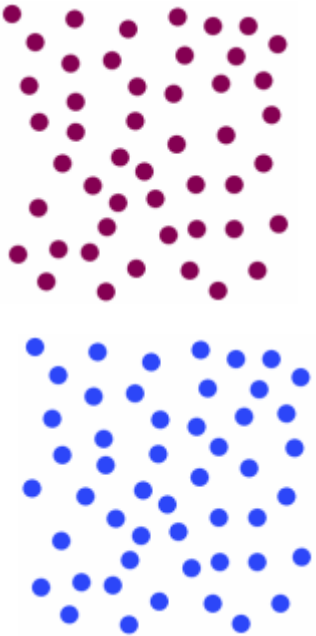
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<http://www.infovis.net/printMag.php?num=179&lang=2>

# Preattentive Processing

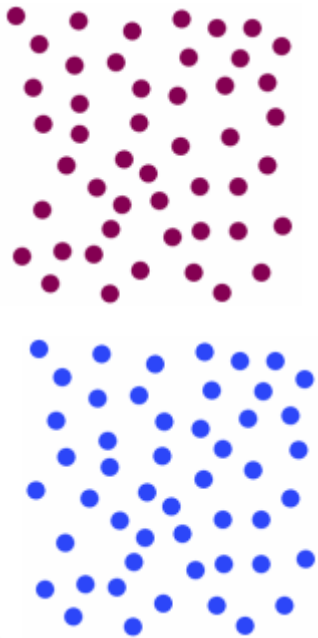
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<http://www.infovis.net/printMag.php?num=179&lang=2>

# Preattentive Processing

- **Instantaneous** detection of outlying elements with no cognitive effort ([Wong 2010](#))



**a**

Easy

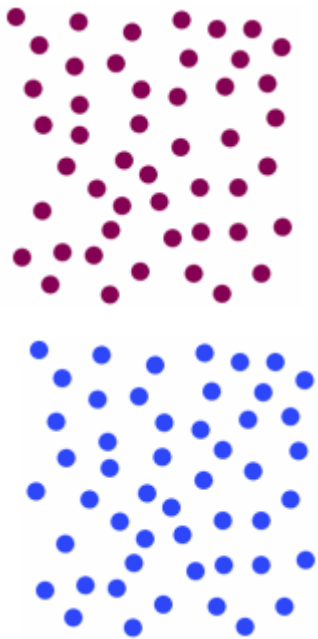
**A**

```
MSVTLHTVFCERTPKTC
EMESRCVPQEGVQWRDL
GSALQPGFGGFKQVFCL
SLPRTGRGGNSIWWGKK
FEDEYSEYSEYLKAVR
GVVSMSNNGPNTNGSQF
FITYGKQPHLDMKYTVF
GKVIDGLEKAPVNEKTY
RPLNDVHIKDITIHNPF
```

<http://www.infovis.net/printMag.php?num=179&lang=2>

# Preattentive Processing

- **Instantaneous** detection of outlying elements with no cognitive effort ([Wong 2010](#))



**a**

Easy  
**A**

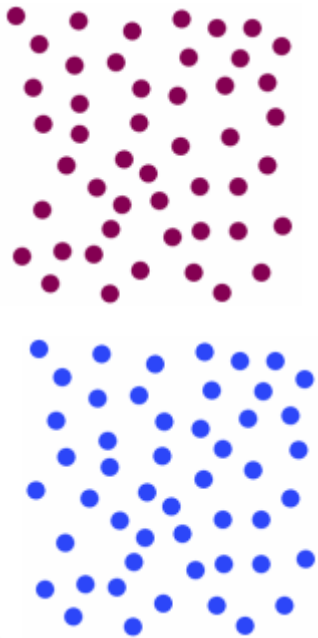
Difficult  
**P**

```
MSVTLHTVFCERTPKTC
EMESRCVPQEGVQWRDL
GSALQPGFGGFKQVFCL
SLPRTGRGGNSIWWGKK
FEDEYSEYSEYLKAVR
GVVSMNNGPNTNGSQF
FITYGKQPHLDMKYTVF
GKVIDGLEKAPVNEKTY
RPLNDVHIKDITIHNPF
```

<http://www.infovis.net/printMag.php?num=179&lang=2>

# Preattentive Processing

- **Instantaneous** detection of outlying elements with no cognitive effort ([Wong 2010](#))



**a**

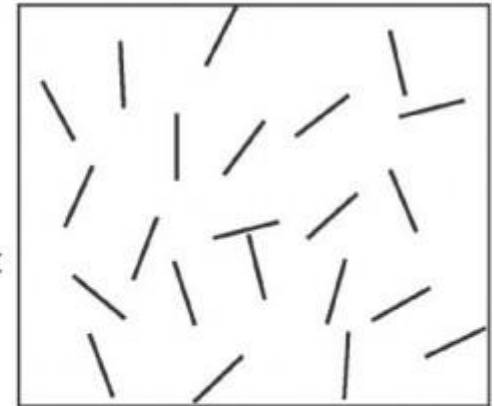
Easy  
A

Difficult  
P

```
MSVTLHTVFCERTPKTC
EMESRCVPQEGVQWRDL
GSALQPGFGGFKQVFCL
SLPRTGRGGNSIWWGKK
FEDEYSEYSEYKHA VR
GVVSMNNGPNTNGSQF
FITYGKQPHLDMKYTVF
GKVIDGLEKAPVNEKTY
RPLNDVHIKDITIHNPF
```

Easy  
T

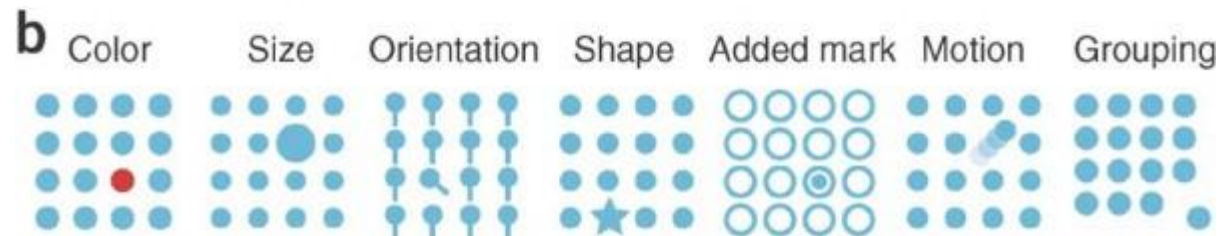
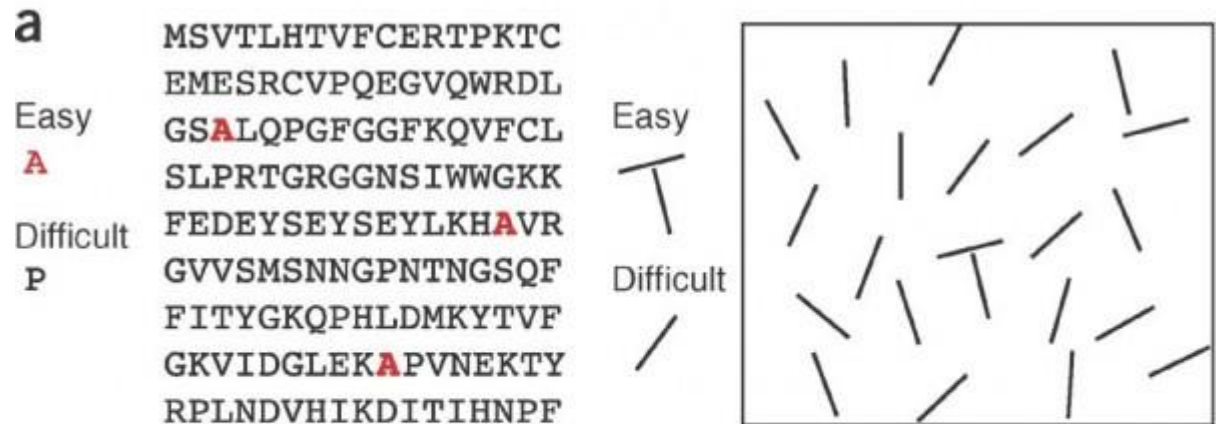
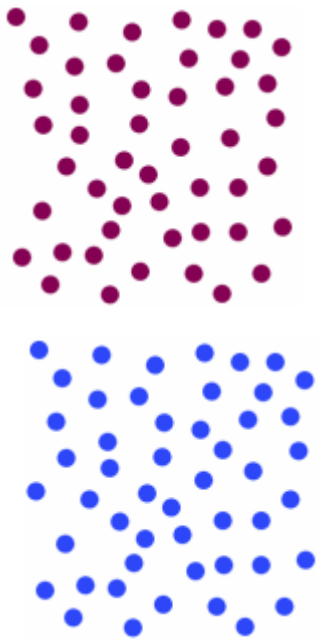
Difficult  
/



<http://www.infovis.net/printMag.php?num=179&lang=2>

# Preattentive Processing

- **Instantaneous** detection of outlying elements with no cognitive effort ([Wong 2010](#))



<http://linkurio.us/graph-viz-101-perceptual-support-of-visualization/>

<http://www.infovis.net/printMag.php?num=179&lang=2>

# Example of pre-attentive processing

- Can you spot the outlier [Haroz&Whitney, InfoVis2012]

# Example of pre-attentive processing

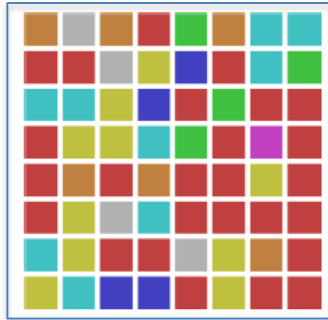
- Can you spot the outlier [Haroz&Whitney, InfoVis2012]





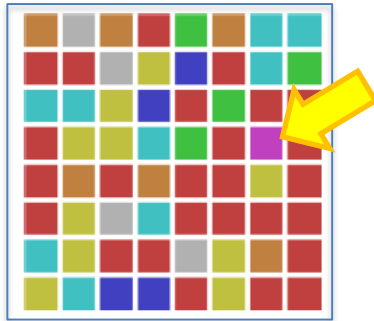
# Example of pre-attentive processing

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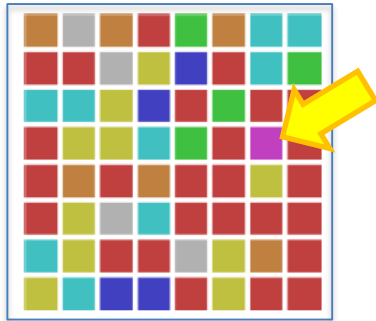
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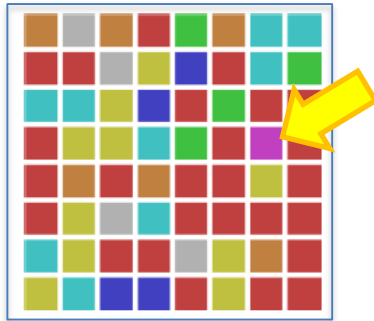
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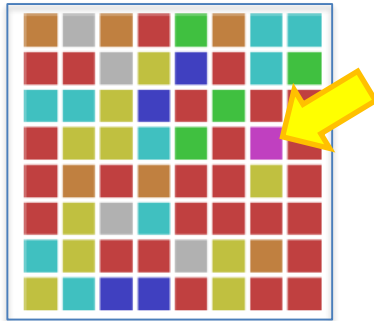
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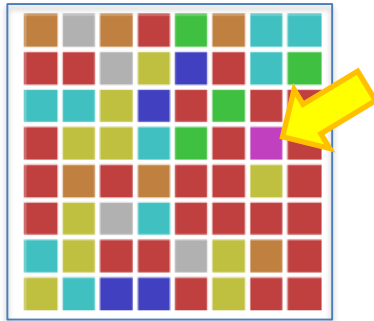
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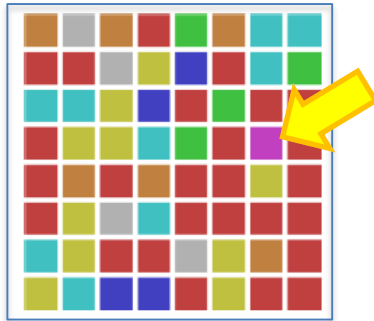
- Can you spot the outlier [Haroz&Whitney, InfoVis2012]



Scanning necessary  
**High cognitive load**  
**Long response time**

# Example of pre-attentive processing

- Can you spot the outlier [Haroz&Whitney, InfoVis2012]



Scanning necessary  
**High cognitive load**  
**Long response time**



Preattentive processing works  
**No cognitive load**  
**Short response time**

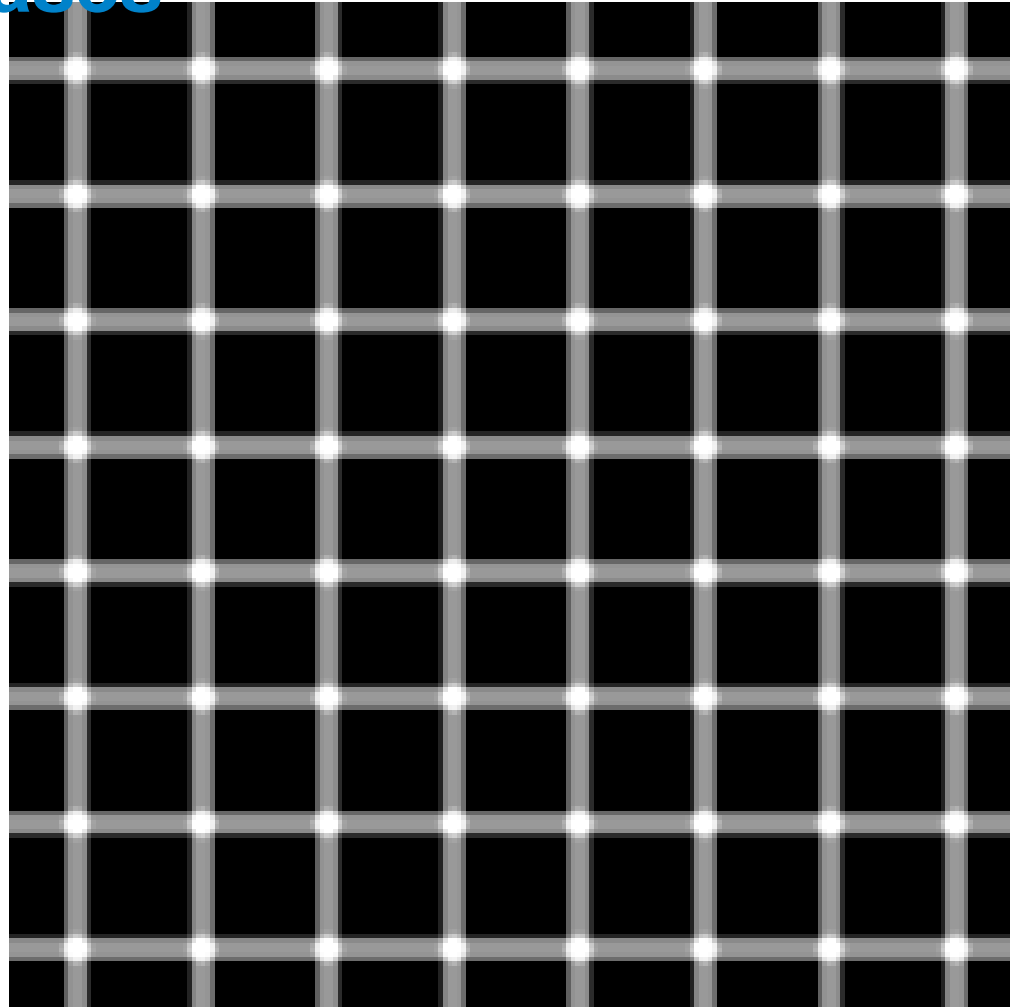
# Visual perception biases

Seeing patterns which do not exist  
(black dots)

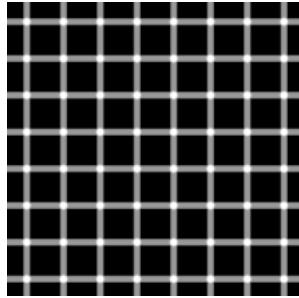


# Visual perception biases

Seeing patterns which do not exist  
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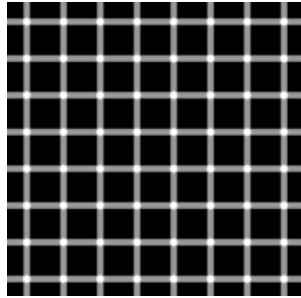


# Visual perception biases

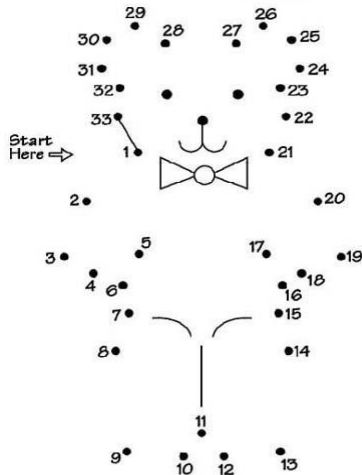
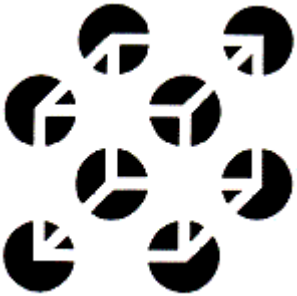


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# Visual perception biases

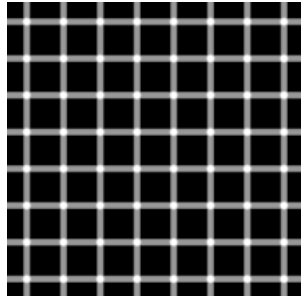


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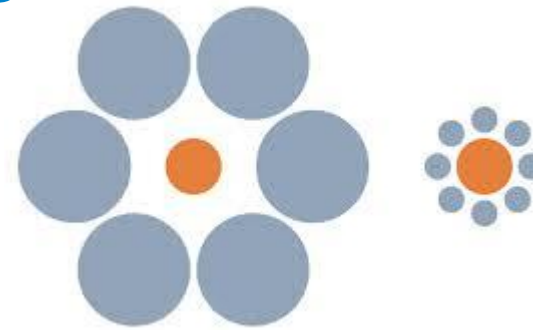


Seeing a structure not in the data

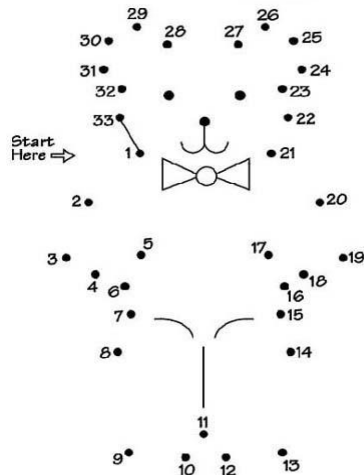
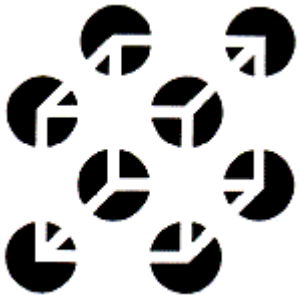
# Visual perception biases



Seeing patterns which do not exist  
(black dots)

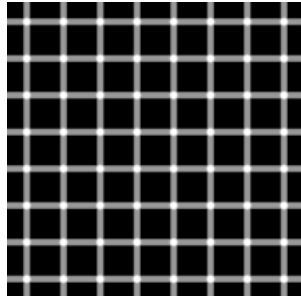


Seeing difference where there is not any

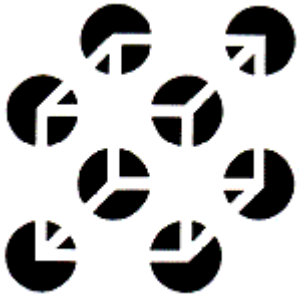


Seeing a structure not in the data

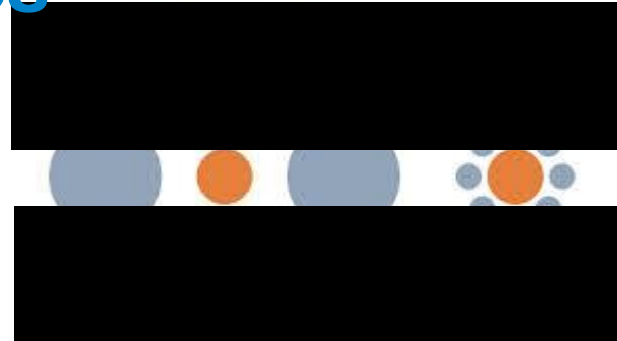
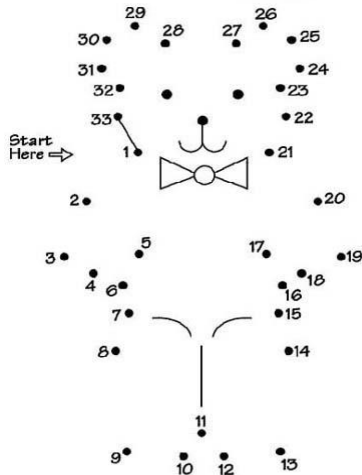
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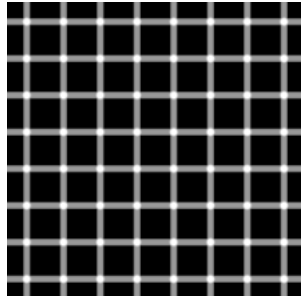
Seeing a structure not in the data



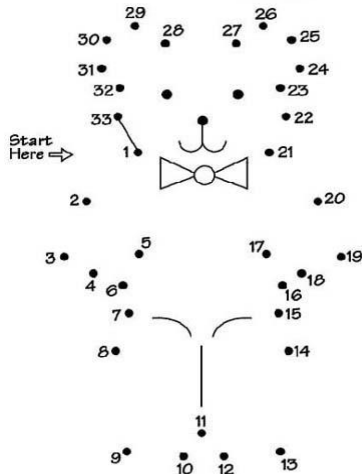
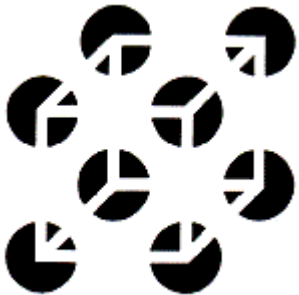
Seeing difference where there is not any



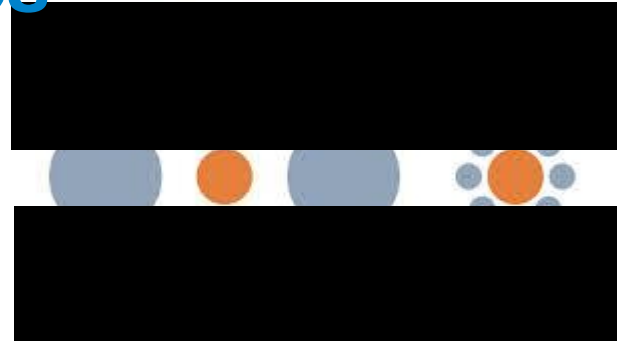
# Visual perception biases



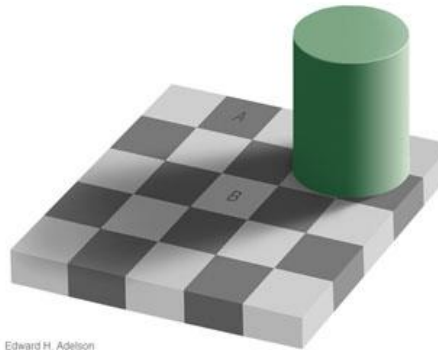
Seeing patterns which do not exist  
(black dots)



Seeing a structure not in the data



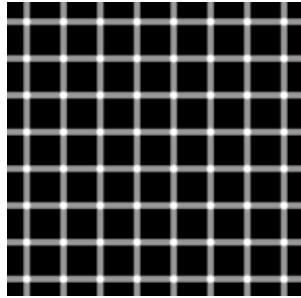
Seeing difference where there is not any



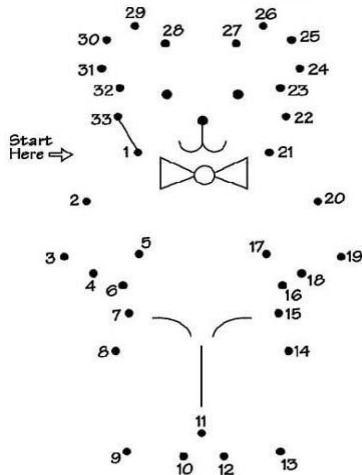
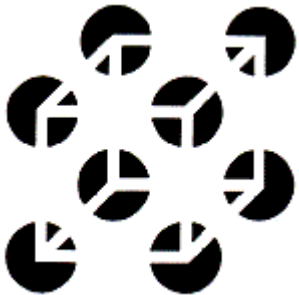
Edward H. Adelson



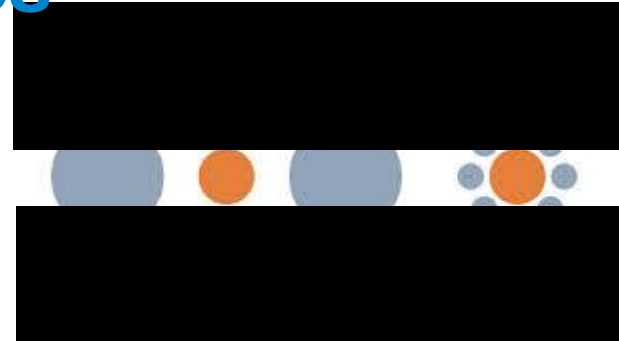
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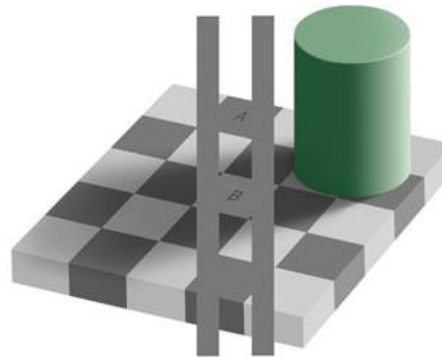
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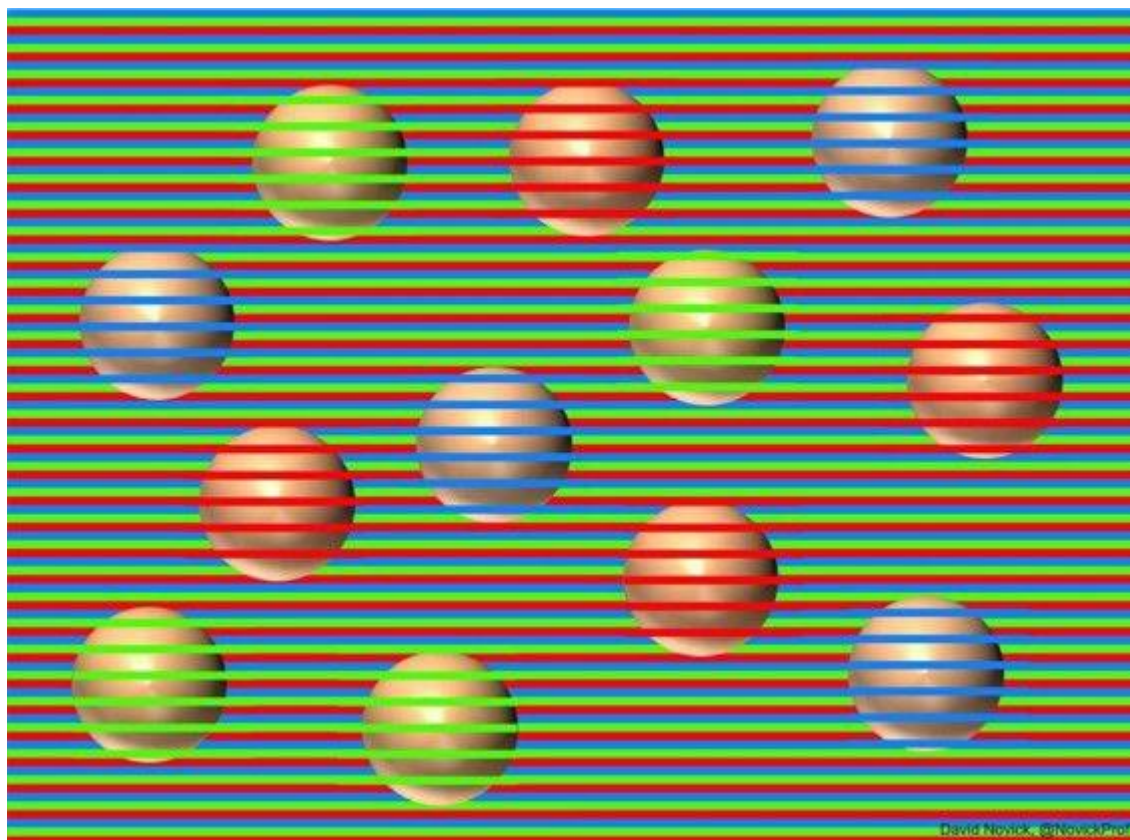


Seeing a structure not in the data



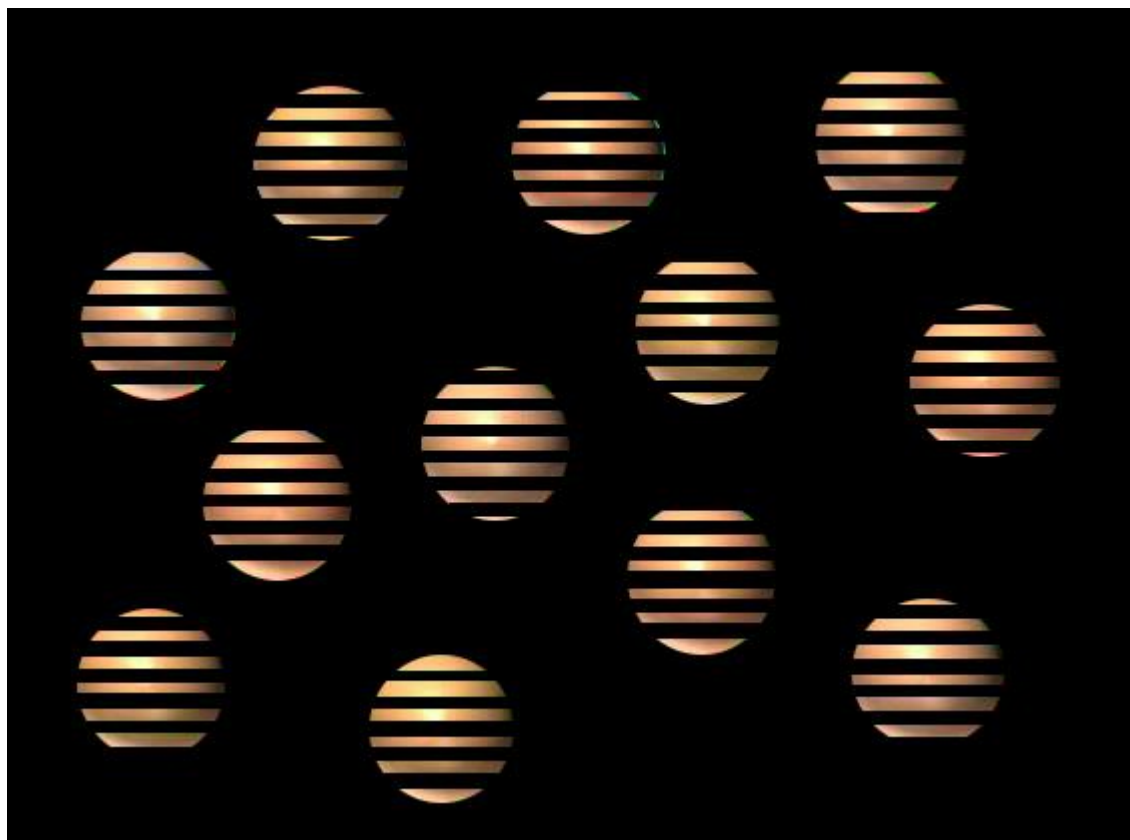
Seeing difference where there is not any





David Novick, @NovickProf





# Cognitive biases

# Cognitive biases

- There is an **old brick wall** with a small **grey pebble** incrustated

Can you **spot** the pebble?

- Is it a small pebble?
- Now that you saw the **cigare** you can hardly see the **pebble**:
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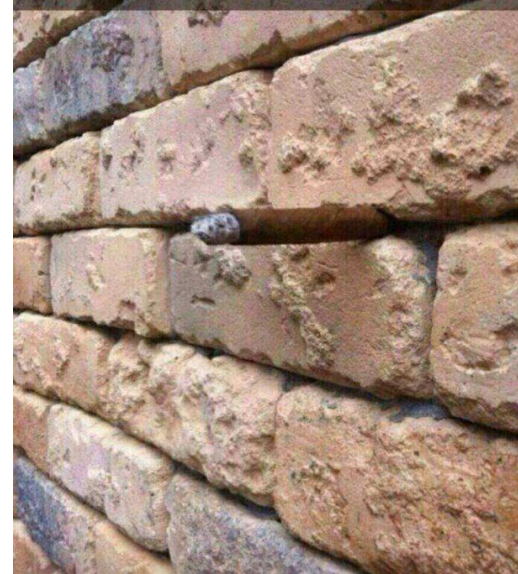
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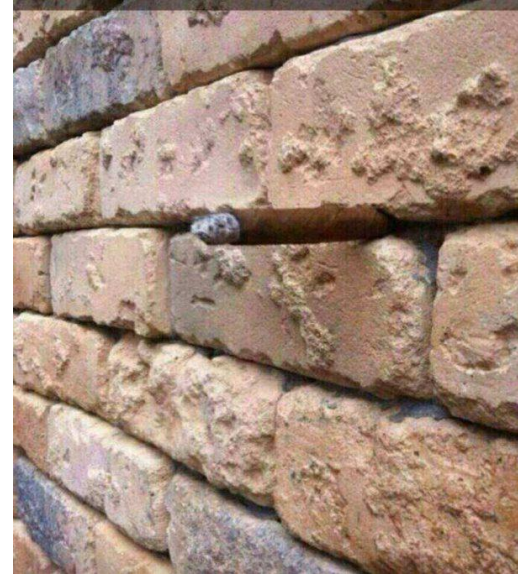


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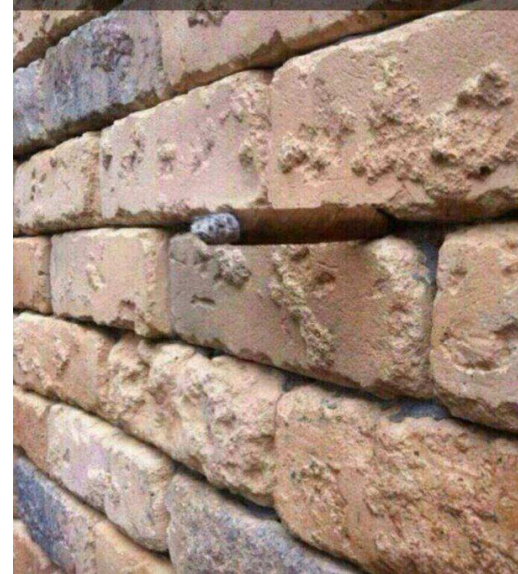


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# More about Visual Perception

- <https://medium.com/@kennelliott/39-studies-about-human-perception-in-30-minutes-4728f9e31a73>

# Outline

- What is Data Visualization?
- User Centered Design
- Visual Perception
- **Criteria for Good Visualizations**
- Some examples
- Resources

# Visualization quality criteria

- **Effectiveness** rather than beauty
  - Display data in a way which leverages on visual perception advantages

# Visualization quality criteria

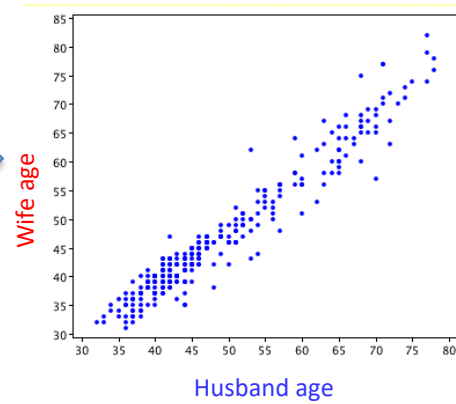
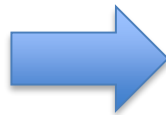
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	Husband age	Wife age
$I_1$	20	19
$I_2$	42	37
$I_3$	35	38
...	...	...

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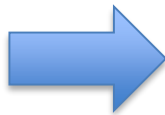
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Aha!

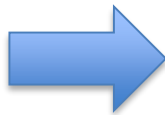
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*“The purpose of visualization is **insight**, not pictures.”* [Shneiderman, 2008]

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## Data distribution

### Quantities to visualize

<i>k</i> th Central Moments:	$\mu_k \simeq \frac{1}{N} \sum_{i=1}^N (x_i - \mu_1)^k$
Mean:	$\mu_1 \simeq \frac{1}{N} \sum_{i=1}^N x_i$
Variance:	$\mu_2 \simeq \frac{1}{N} \sum_{i=1}^N (x_i - \mu_1)^2$
Standard Deviation:	$\sigma = \sqrt{\mu_2}$
Skew:	$\gamma = \frac{\mu_3}{\sigma^3}$
Kurtosis:	$\kappa = \frac{\mu_4}{\sigma^4}$
Excess Kurtosis:	$\kappa_e = \kappa - 3$
Tailing:	$\tau = \frac{\mu_4}{\sigma^4}$

# Visualization quality criteria

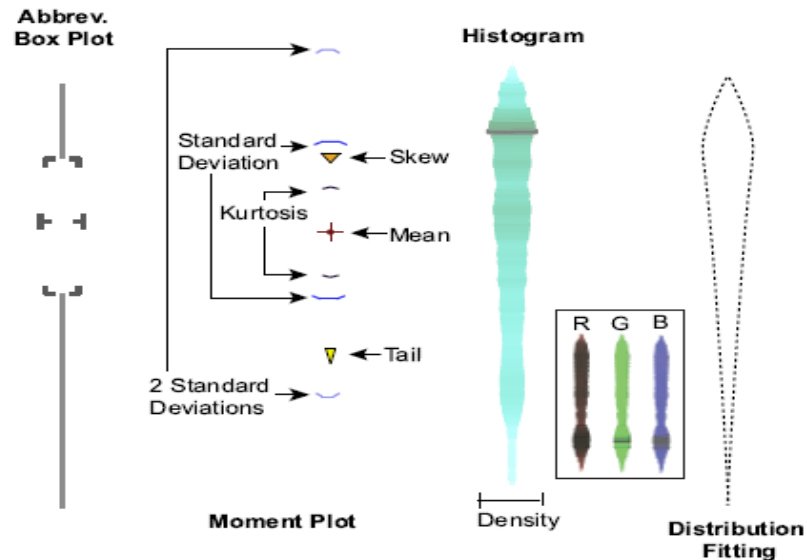
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## Visual metaphors:



# Visualization quality criteria

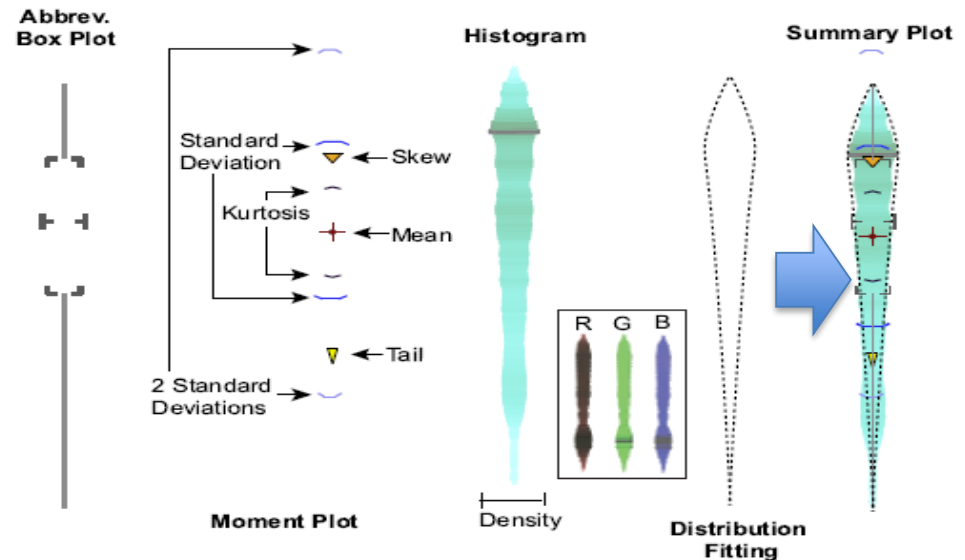
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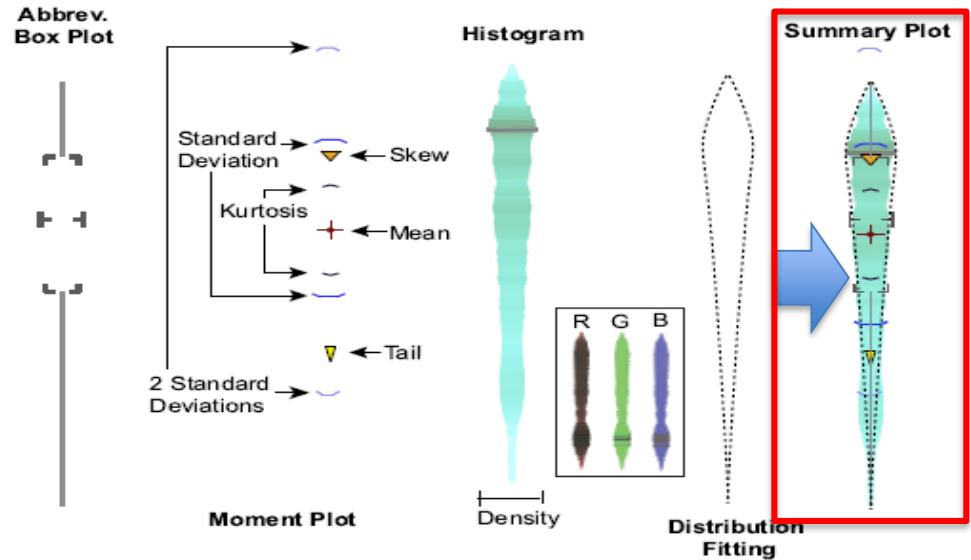
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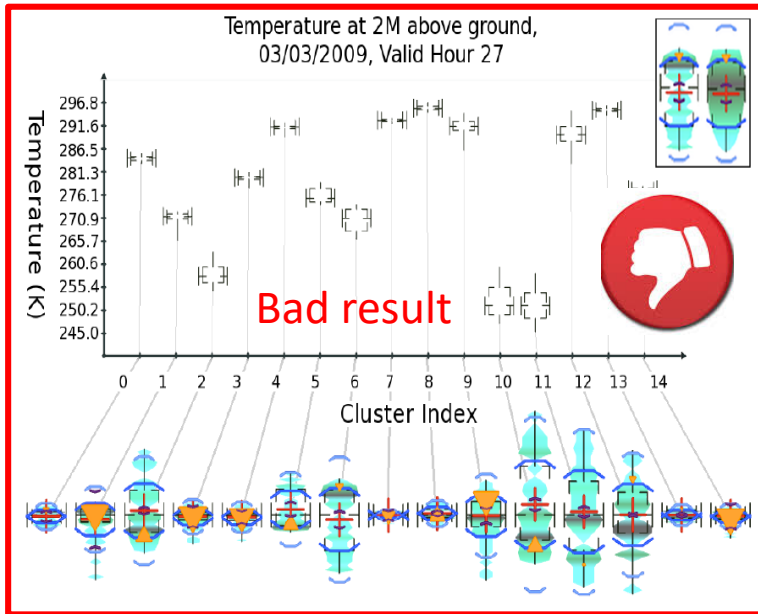
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**Bad:** try to show too many info at a time

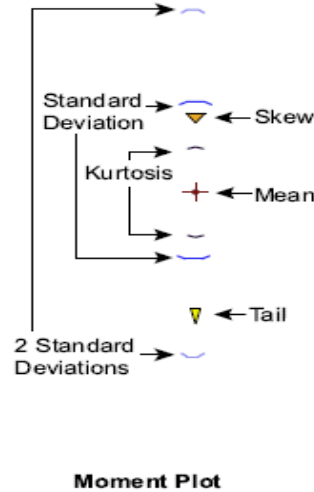
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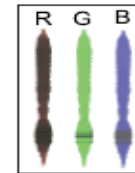


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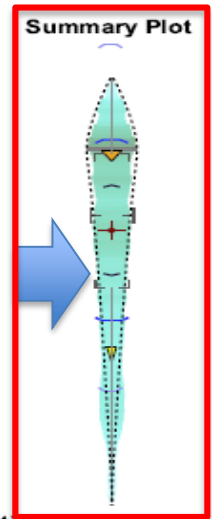
Abbrev. Box Plot



Histogram



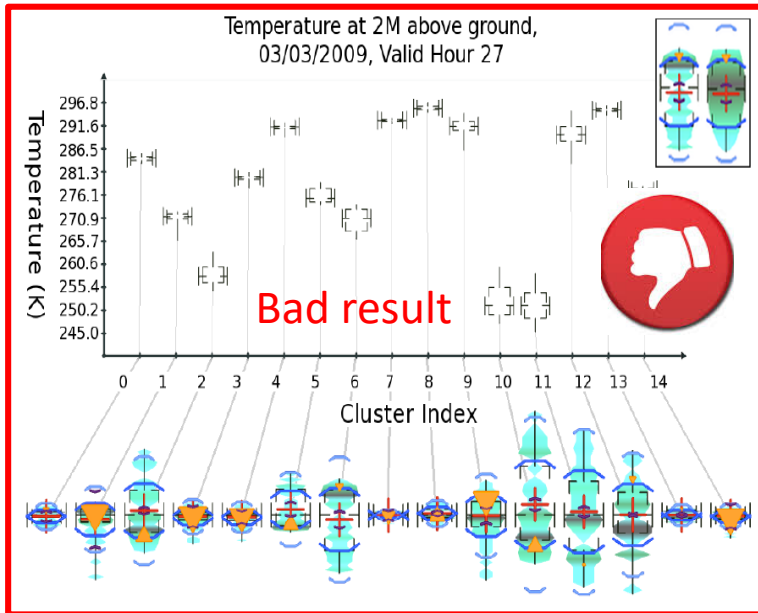
Distribution Fitting



**Bad:** try to show too many info at a time

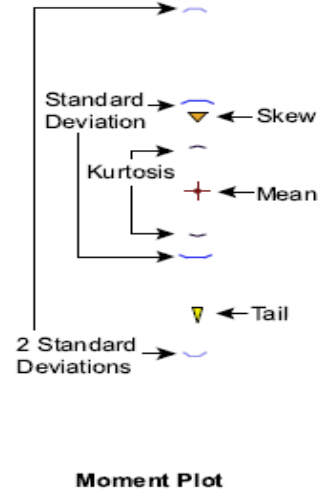
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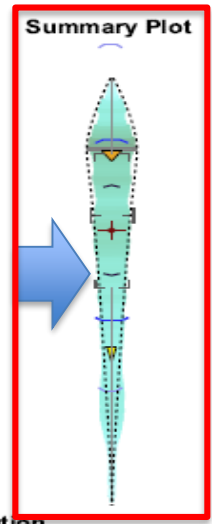
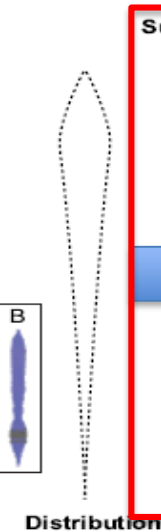
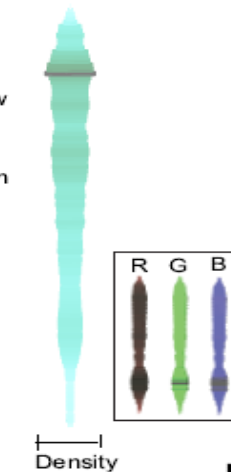


Visual metaphors:

Abbrev.  
Box Plot



Histogram



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Visual information seeking mantra

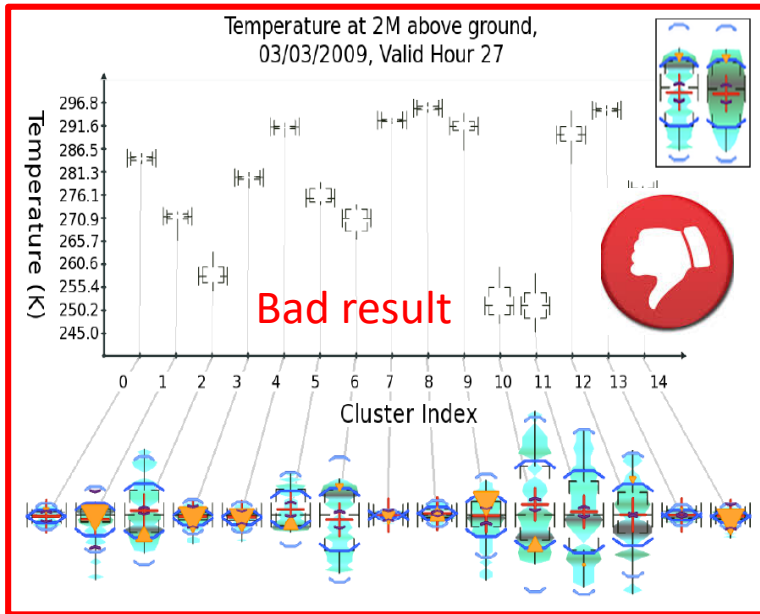
“**Overview** first, **zoom** and **filter**, then **details-on-demand**.” [Shneiderman, 1996]





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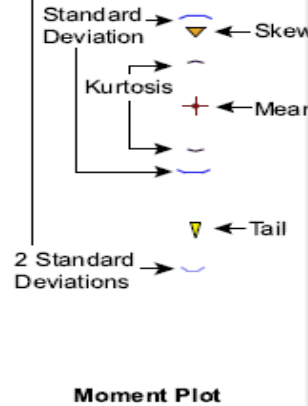


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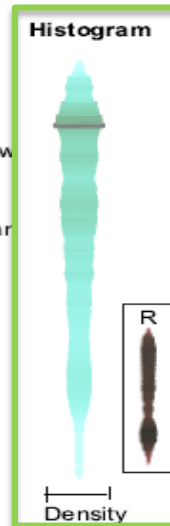
Abbrev. Box Plot



**Good overview**

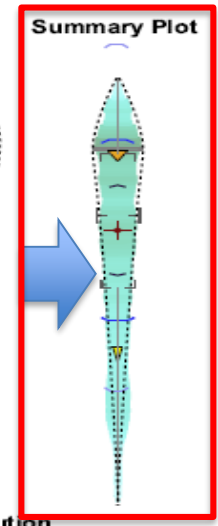


Moment Plot



Density

**Bad: try to show too many info at a time**



Distribution

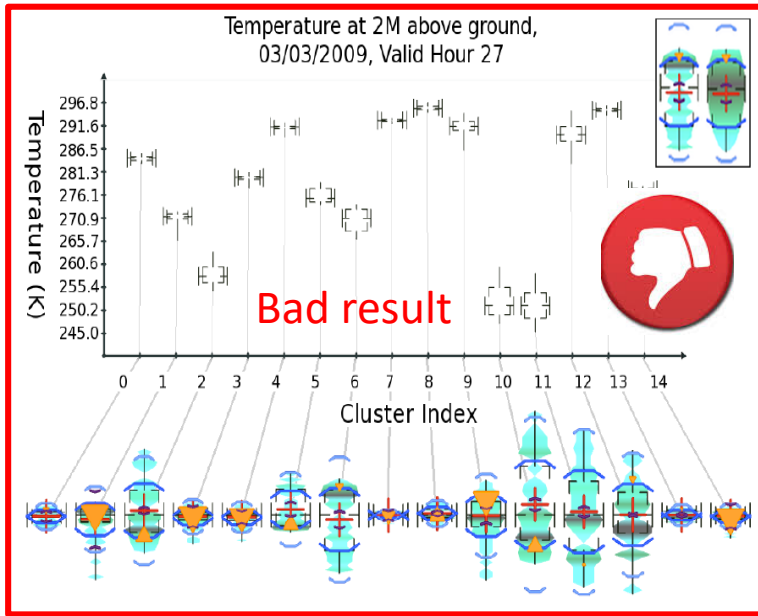


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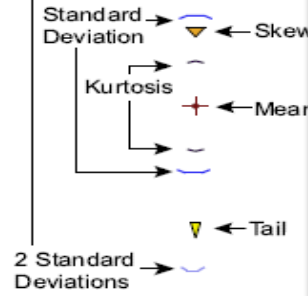


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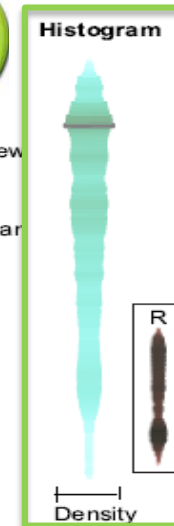
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Moment Plot

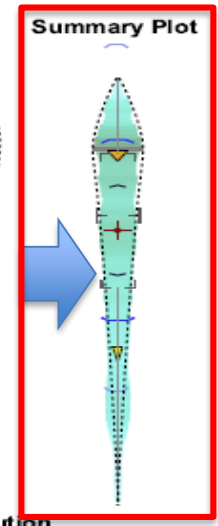


Density

**Bad: try to show too many info at a time**



Distribution



Summary Plot



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Interaction is needed

# Visualization quality criteria

- **Data to ink ratio**

$$= \frac{\text{Data-ink}}{\text{Total ink used to print the graphic}}$$

= proportion of a graphic's ink devoted to the non-redundant display of data-information

= 1.0 – proportion of a graphic that can be erased

[http://www.infovis-wiki.net/index.php/Data-Ink\\_Ratio](http://www.infovis-wiki.net/index.php/Data-Ink_Ratio)

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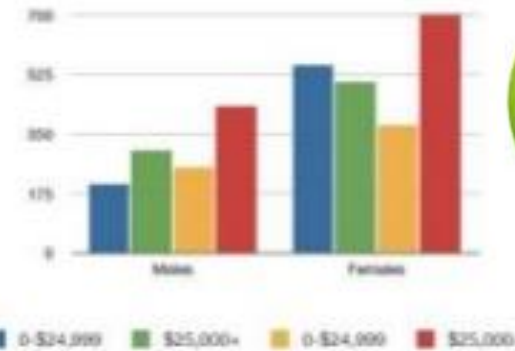
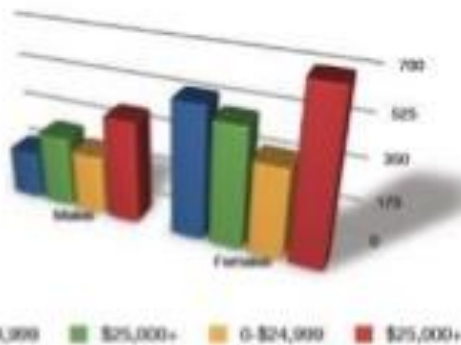
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# Visualization quality criteria

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- Principle of **inertia**

- *A large share of ink on a graphic should present data-information, **the ink changing as [and only as] the data change**. Data-ink is the non-erasable core of a graphic, the non-redundant ink arranged in response to variation in the numbers represented. [Tufte, 1983]*
- Any graphical **variation** is explained as a **change** in the underlying data in the user's mind
- Irrelevant graphical variation not guided **by** data change induces **false inference** and **higher cognitive load** on **the** user

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# What makes a good graphical encoding

- There is **no one-size-fits-all** visualization
- One visualization is optimized to answer a small set of questions

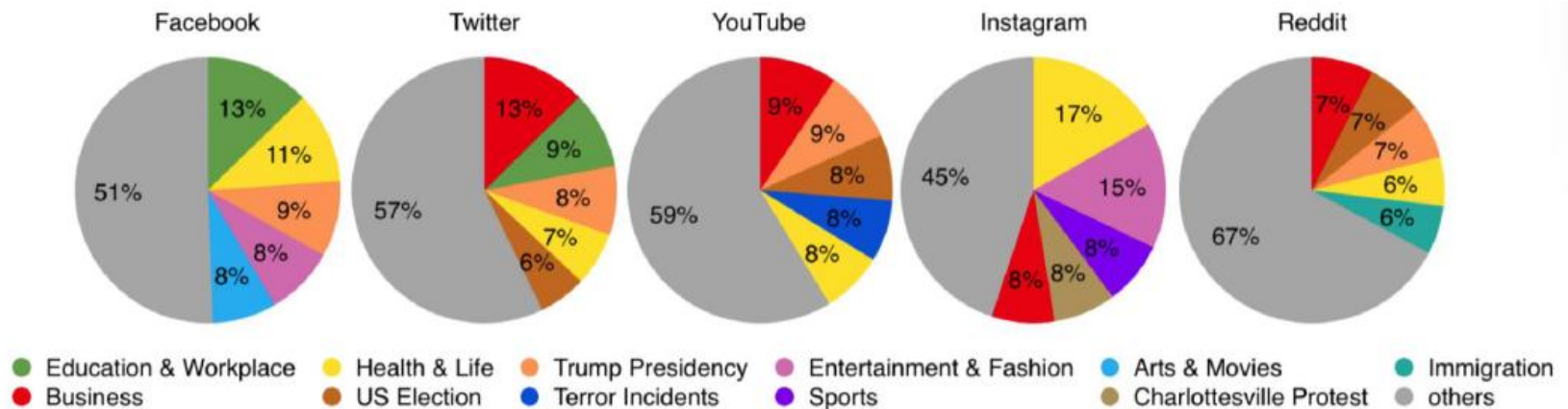
## Platforms and top 5 Popular Topics

	Facebook	Twitter	YouTube	Instagram	Reddit
Education & Workplace	13	9	-	-	-
Business	-	13	9	8	7
Health&Life	11	7	8	17	-
US Election	-	6	8	-	7
Trump Presidency	9	8	-	-	7
Terror Incidents	-	-	8	-	-
Entertainment&Fashion	8	-	-	15	-
Sports	-	-	-	8	-
Arts&Movies	8	-	-	-	-
Charlottesville Protest	-	-	-	8	-
Immigration	-	-	-	-	6
Others	51	57	59	45	67

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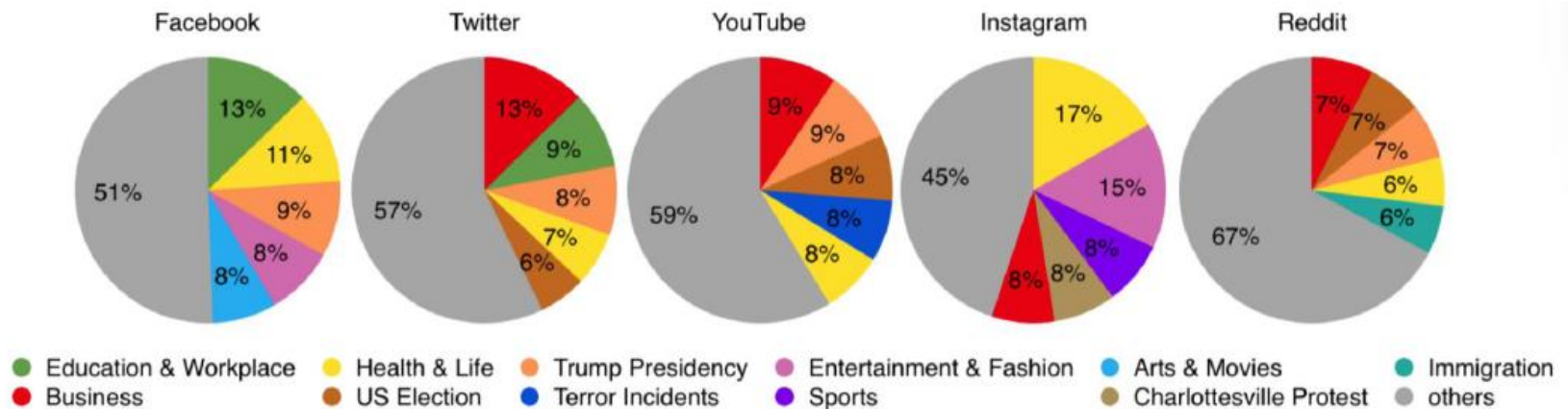
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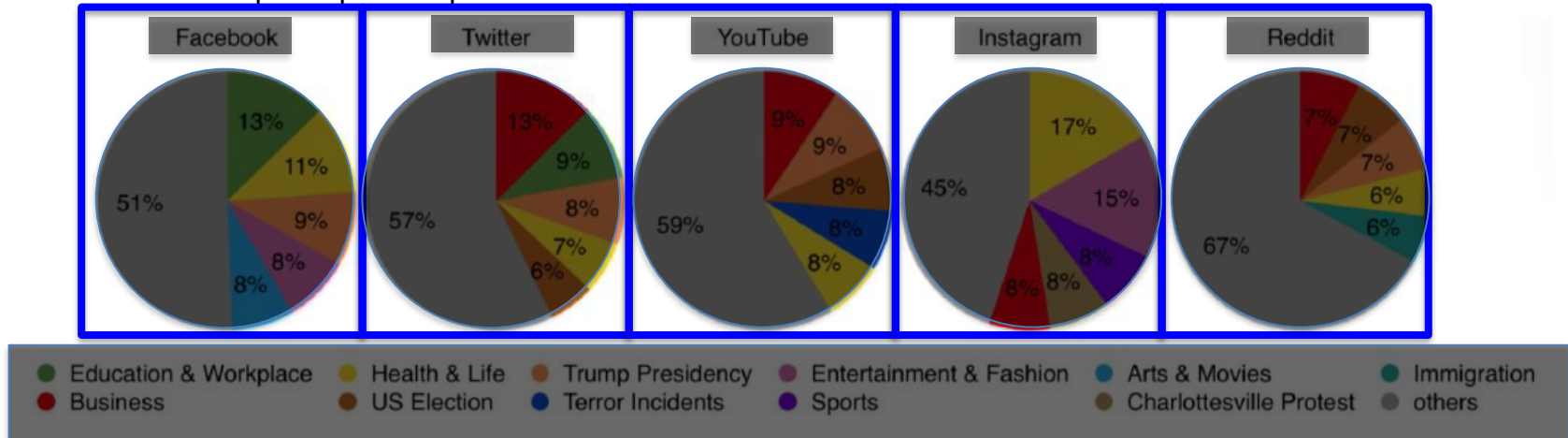
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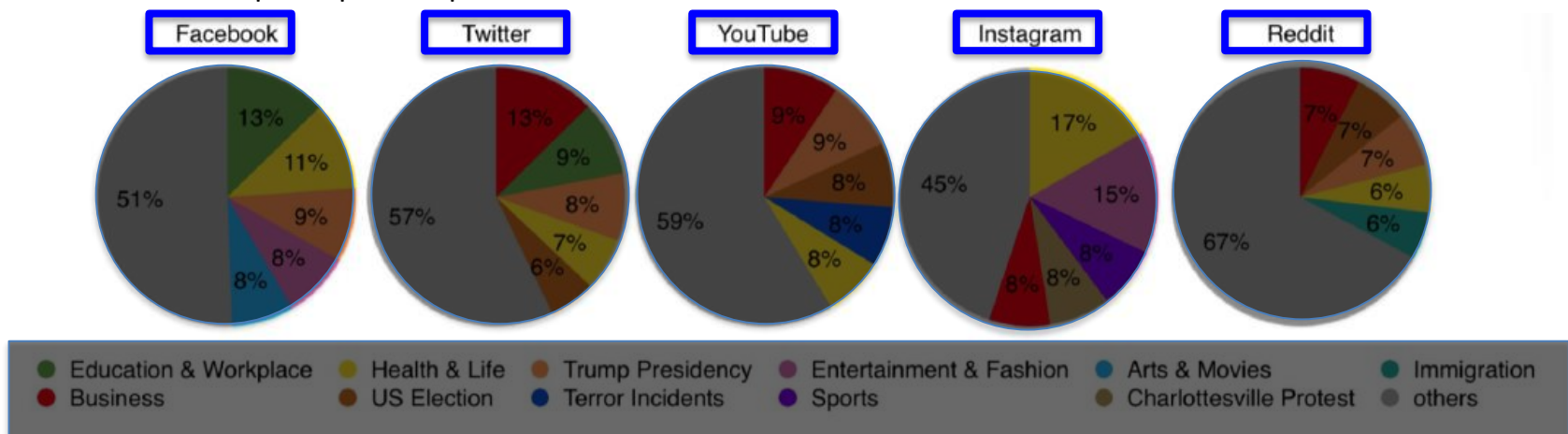
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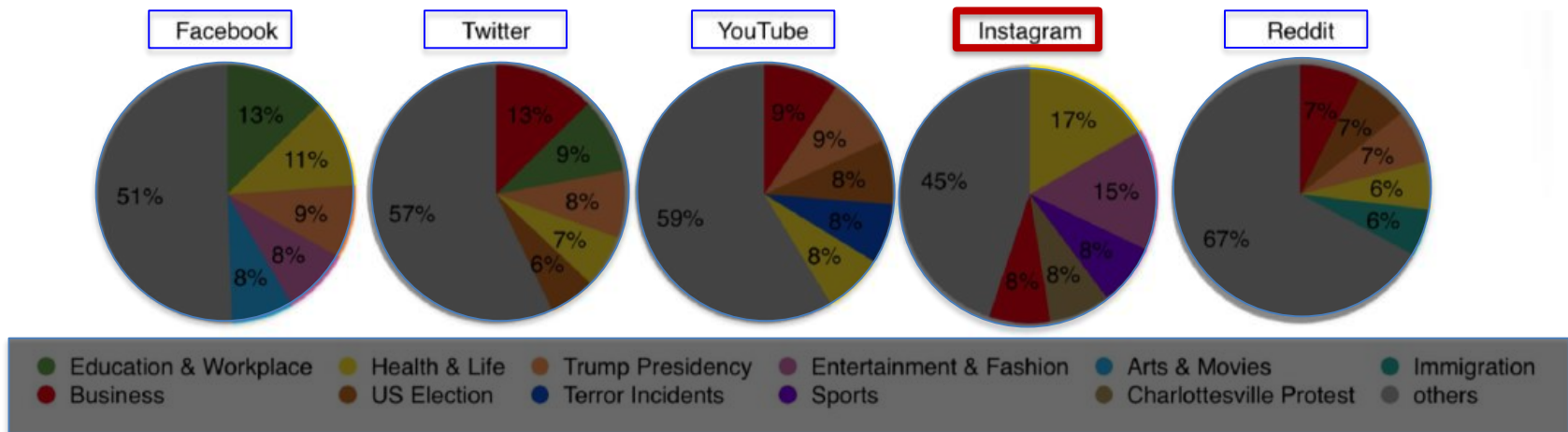
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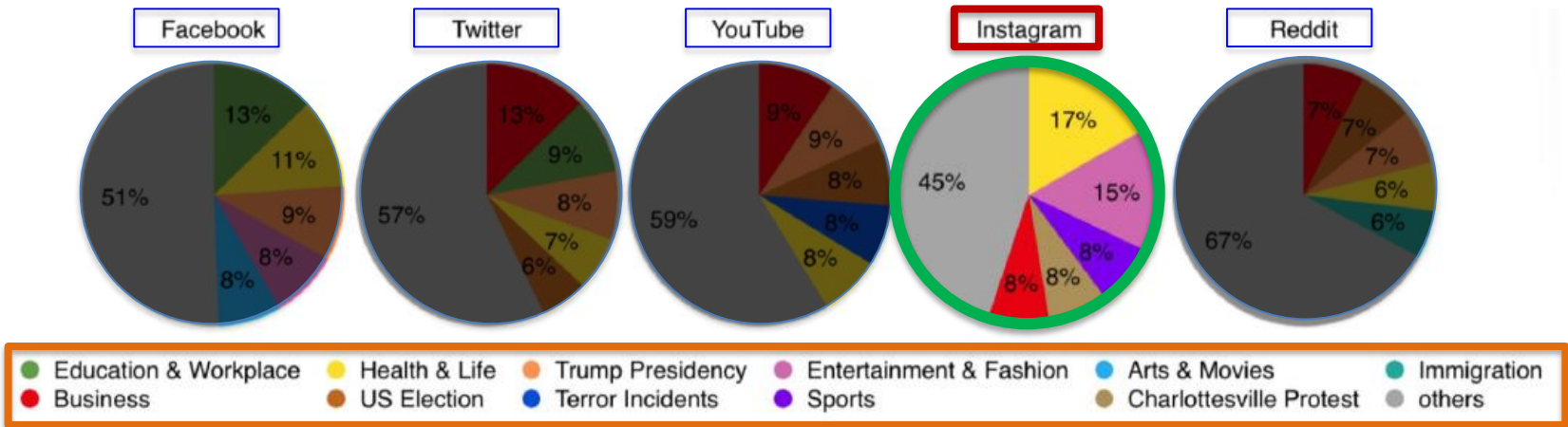
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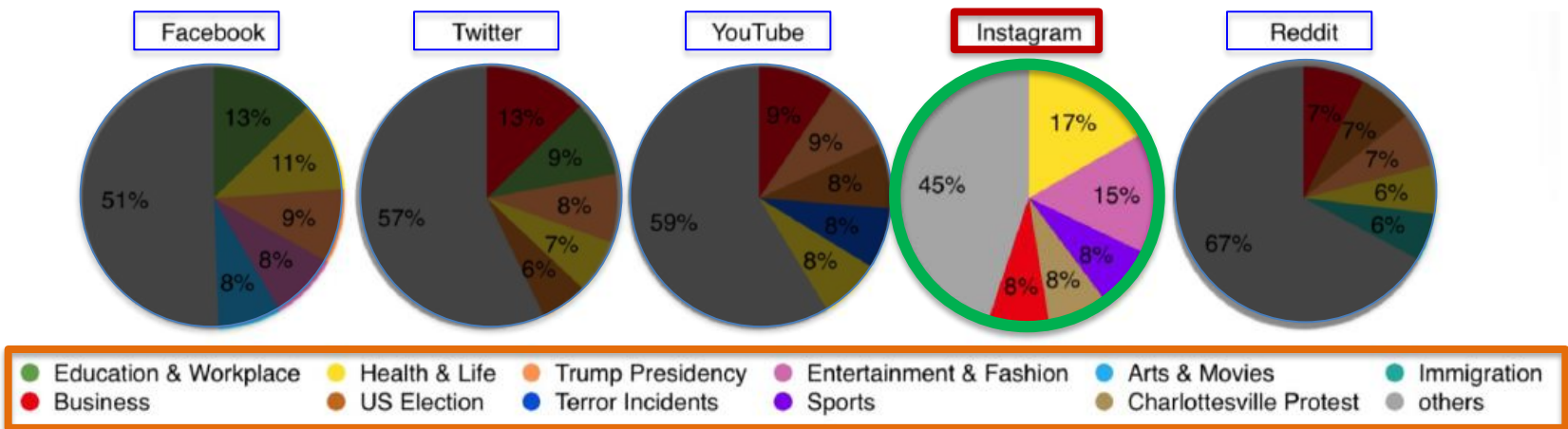
Hierarchy: Platform -> Proportions -> Topics



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Platforms and top 5 Popular Topics



What task is optimized with this graphic?

Question it supports:

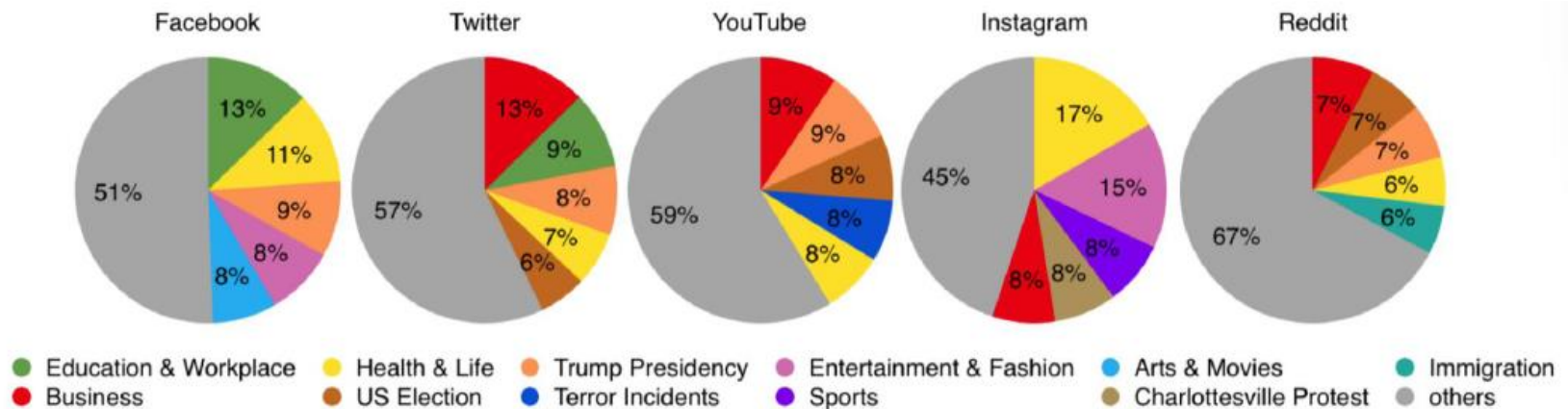
“What are the **proportions** of **top 5 topics** of platform **Y?**”



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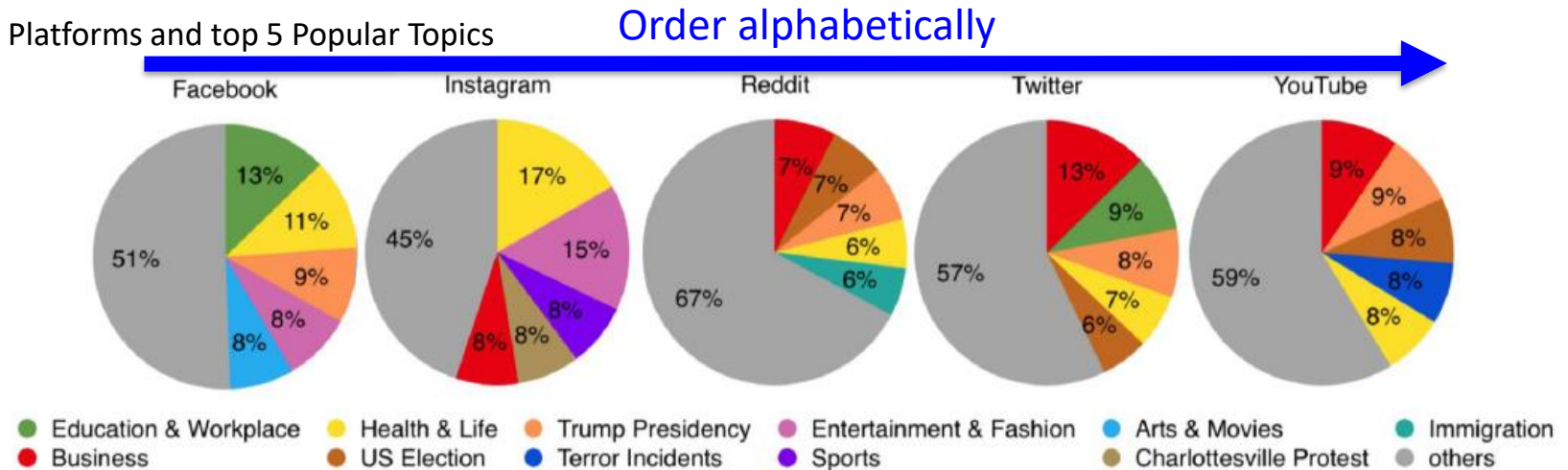
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“What are the proportions of top 5 topics of platform Y?”

Can we improve that chart?

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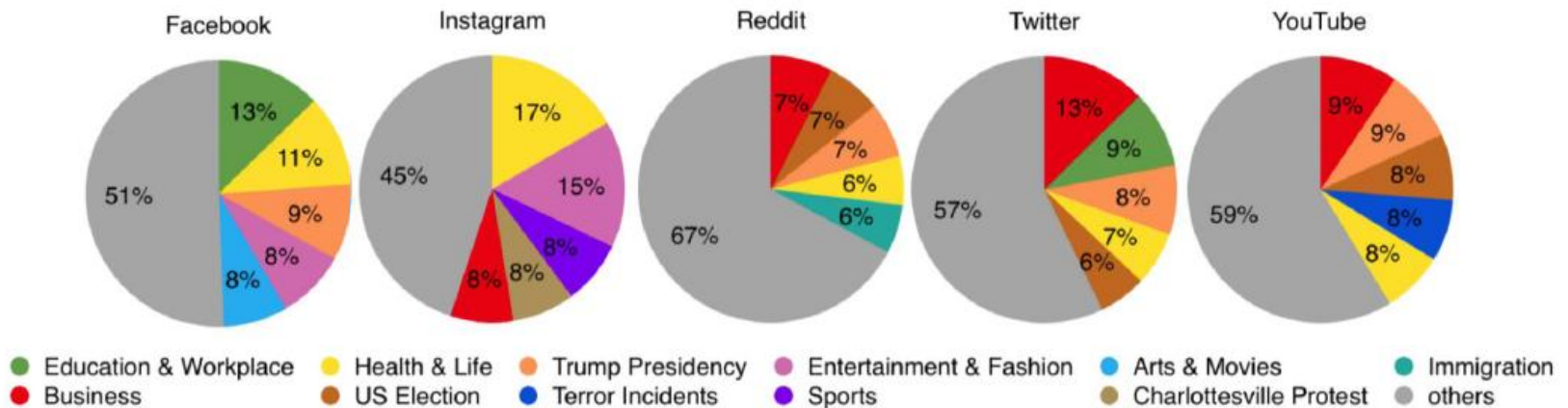
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Can we improve that chart?

# What makes a good graphical encoding

- There is **no one-size-fits-all** visualization
- One visualization is optimized to answer a small set of questions

Platforms and top 5 Popular Topics

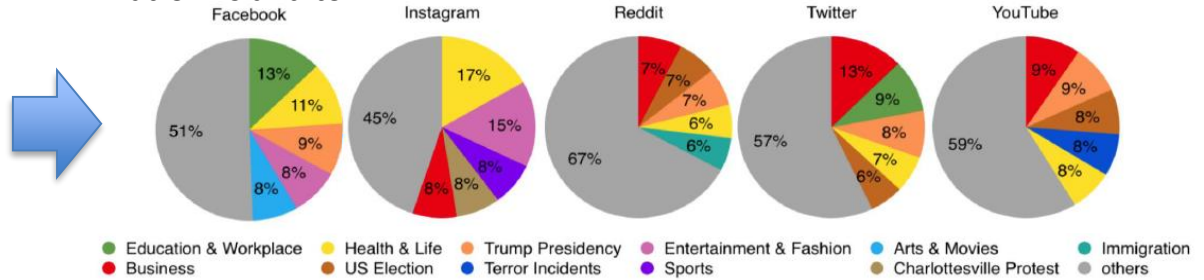


How should we draw the same data to better support answering :

“What is the platform most popular for Health & Life topic” ?

	Facebook	Twitter	YouTube	Instagram	Reddit
Education & Workplace	13	9	-	-	-
Business	-	13	9	8	7
Health&Life	11	7	8	17	-
US Election	-	6	8	-	7
Trump Presidency	9	8	-	-	7
Terror Incidents	-	-	8	-	-
Entertainment&Fashion	8	-	-	15	-
Sports	-	-	-	8	-
Arts&Movies	8	-	-	-	-
Charlottesville Protest	-	-	-	8	-
Immigration	-	-	-	-	6
Others	51	57	59	45	67

### Platforms and top 5 Popular Topics



# What makes a good graphical encoding

- Complex questions may require **interactive techniques**, or coordinated views

- <https://ptable.com/#Writeup/Wikipedia>

Search

Ptable

Wikipedia Properties Orbitals Isotopes Compounds

Weight  Names  Electrons  Wide

FT  
FINANCIAL TIMES

Don't decide until you subscribe

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18

1 H Atomic Sym  
Hydrogen Name  
1.008 Weight

2 He  
Helium  
4.0026

3 Li  
Lithium  
6.94

4 Be  
Beryllium  
9.0122

5 B  
Boron  
10.81

6 C  
Carbon  
12.011

7 N  
Nitrogen  
14.007

8 O  
Oxygen  
15.999

9 F  
Fluorine  
18.998

10 Ne  
Neon  
20.180

11 Na  
Sodium  
22.990

12 Mg  
Magnesium  
24.305

13 Al  
Aluminum  
26.982

14 Si  
Silicon  
28.085

15 P  
Phosphorus  
30.974

16 S  
Sulfur  
32.06

17 Cl  
Chlorine  
35.45

18 Ar  
Argon  
39.948

19 K  
Potassium  
39.098

20 Ca  
Calcium  
40.078

21 Sc  
Scandium  
44.956

22 Ti  
Titanium  
47.867

23 V  
Vanadium  
50.942

24 Cr  
Chromium  
51.996

25 Mn  
Manganese  
54.938

26 Fe  
Iron  
55.845

27 Co  
Cobalt  
58.933

28 Ni  
Nickel  
58.693

29 Cu  
Copper  
63.546

30 Zn  
Zinc  
65.38

31 Ga  
Gallium  
69.723

32 Ge  
Germanium  
72.630

33 As  
Arsenic  
74.922

34 Se  
Selenium  
78.971

35 Br  
Bromine  
79.904

36 Kr  
Krypton  
83.798

37 Rb  
Rubidium  
85.468

38 Sr  
Strontium  
87.62

39 Y  
Yttrium  
88.906

40 Zr  
Zirconium  
91.224

41 Nb  
Niobium  
92.906

42 Mo  
Molybdenum  
95.95

43 Tc  
Technetium  
(98)

44 Ru  
Ruthenium  
101.07

45 Rh  
Rhodium  
102.91

46 Pd  
Palladium  
106.42

47 Ag  
Silver  
107.87

48 Cd  
Cadmium  
112.41

49 In  
Indium  
114.82

50 Sn  
Tin  
117.71

51 Sb  
Antimony  
121.75

52 Te  
Tellurium  
127.60

53 I  
Iodine  
126.90

54 Xe  
Xenon  
131.29

55 Cs  
Caesium  
132.91

56 Ba  
Barium  
137.33

57-71  
Lanthanoids

58 La  
Lanthanum  
138.91

59 Ce  
Cerium  
140.12

60 Pr  
Praseodymium  
140.91

61 Nd  
Neodymium  
144.24

62 Sm  
Samarium  
150.36

63 Eu  
Europium  
151.96

64 Gd  
Gadolinium  
157.25

65 Tb  
Terbium  
158.93

66 Dy  
Dysprosium  
162.50

67 Ho  
Holmium  
164.93

68 Er  
Erbium  
167.26

69 Tm  
Thulium  
168.93

70 Yb  
Ytterbium  
173.05

71 Lu  
Lutetium  
174.97

72 Hf  
Hafnium  
178.49

73 Ta  
Tantalum  
180.95

74 W  
Tungsten  
183.84

75 Re  
Rhenium  
186.21

76 Os  
Osmium  
190.23

77 Ir  
Iridium  
192.22

78 Pt  
Platinum  
195.08

79 Au  
Gold  
196.97

80 Hg  
Mercury  
200.59

81 Tl  
Thallium  
204.38

82 Pb  
Lead  
207.2

83 Bi  
Bismuth  
208.98

84 Po  
Polonium  
(209)

85 At  
Astatine  
(210)

86 Rn  
Radon  
(222)

87 Fr  
Francium  
(223)

88 Ra  
Radium  
(226)

89-103  
Actinoids

89 Ac  
Actinium  
(227)

90 Th  
Thorium  
(232.04)

91 Pa  
Protactinium  
(231.04)

92 U  
Uranium  
(238.03)

93 Np  
Neptunium  
(237)

94 Pu  
Plutonium  
(244)

95 Am  
Americium  
(243)

96 Cm  
Curium  
(247)

97 Bk  
Berkelium  
(247)

98 Cf  
Californium  
(251)

99 Es  
Einsteinium  
(252)

100 Fm  
Fermium  
(257)

101 Md  
Mendelevium  
(258)

102 No  
Nobelium  
(259)

103 Lr  
Lawrencium  
(260)

104 Rf  
Rutherfordium  
(261)

105 Db  
Dubnium  
(262)

106 Sg  
Seaborgium  
(263)

107 Bh  
Bohrium  
(264)

108 Hs  
Hassium  
(265)

109 Mt  
Meitnerium  
(266)

110 Ds  
Darmstadtium  
(267)

111 Rg  
Roentgenium  
(268)

112 Cn  
Copernicium  
(269)

113 Nh  
Nihonium  
(270)

114 Fl  
Flerovium  
(271)

115 Mc  
Moscovium  
(272)

116 Lv  
Livermorium  
(273)

117 Ts  
Tennessine  
(274)

118 Og  
Oganesson  
(274)

For elements with no stable isotopes, the mass number of the isotope with the longest half-life is in parentheses.

Periodic Table Design & Interface Copyright © 1997 Michael Dayah Ptable.com Last updated Jun 16, 2017

DEMO ABOUT CONTACT POSTER PRINT IMAGE REMOVE ADS LESSON PLANS DISCORD English

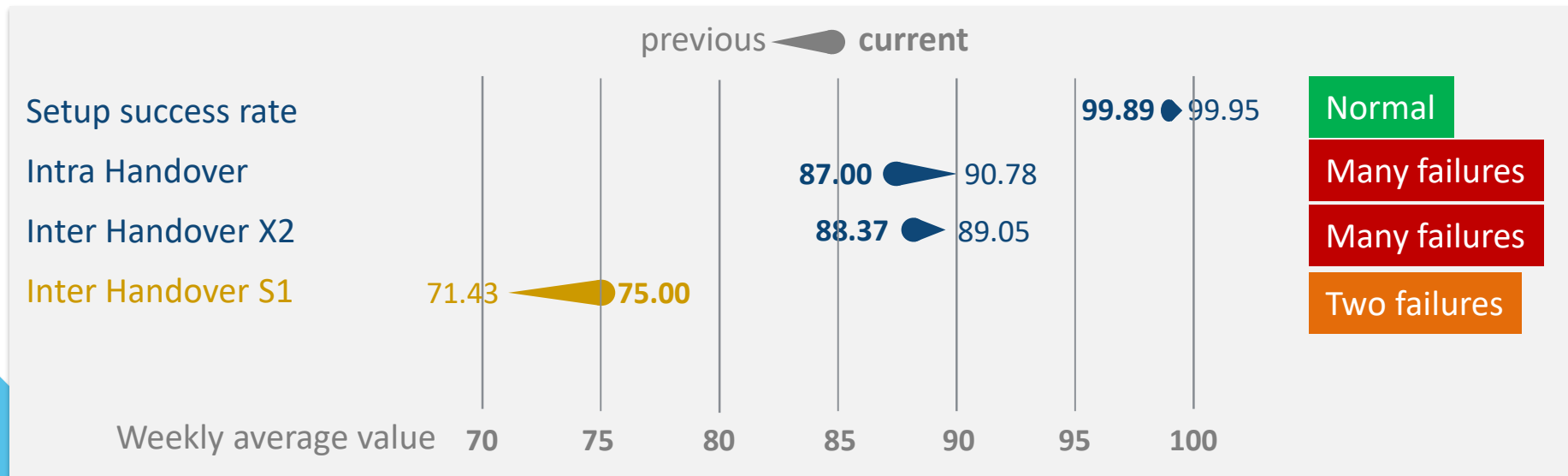
© 2017 MICHAEL DAYAH VINYL BANNERS PRINTED BY PRINTASTIC

# Example of re-design

NE	KPI Title	Unit	Average values previous week	Average values current week	Comment
RAN	inter Handover X2	%	89.05	88.37	Many Failures Location 1
RAN	inter Handover S1	%	71.43	75.00	2 Failures Location 2
RAN	intra Handover	%	90.78	87.00	Many Failures Location 3
RAN	Setup success rate	%	99.95	99.89	Normal

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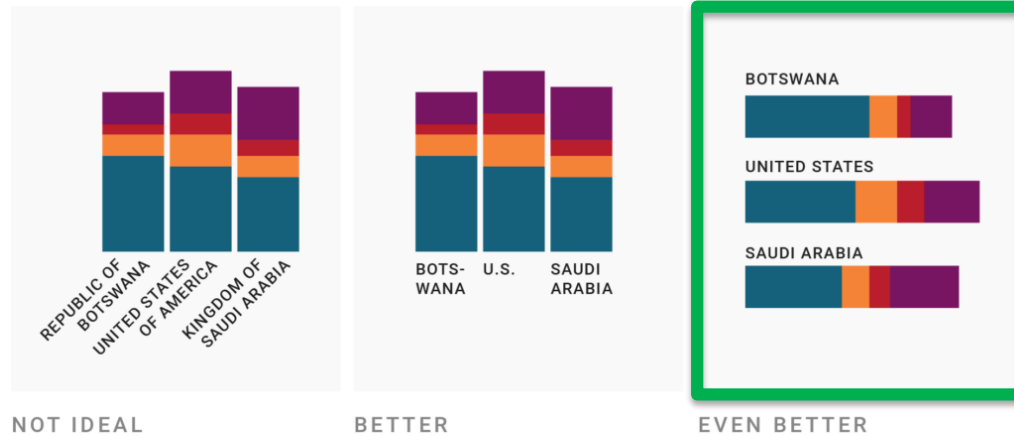
M. Aupetit - QCRI



# Outline

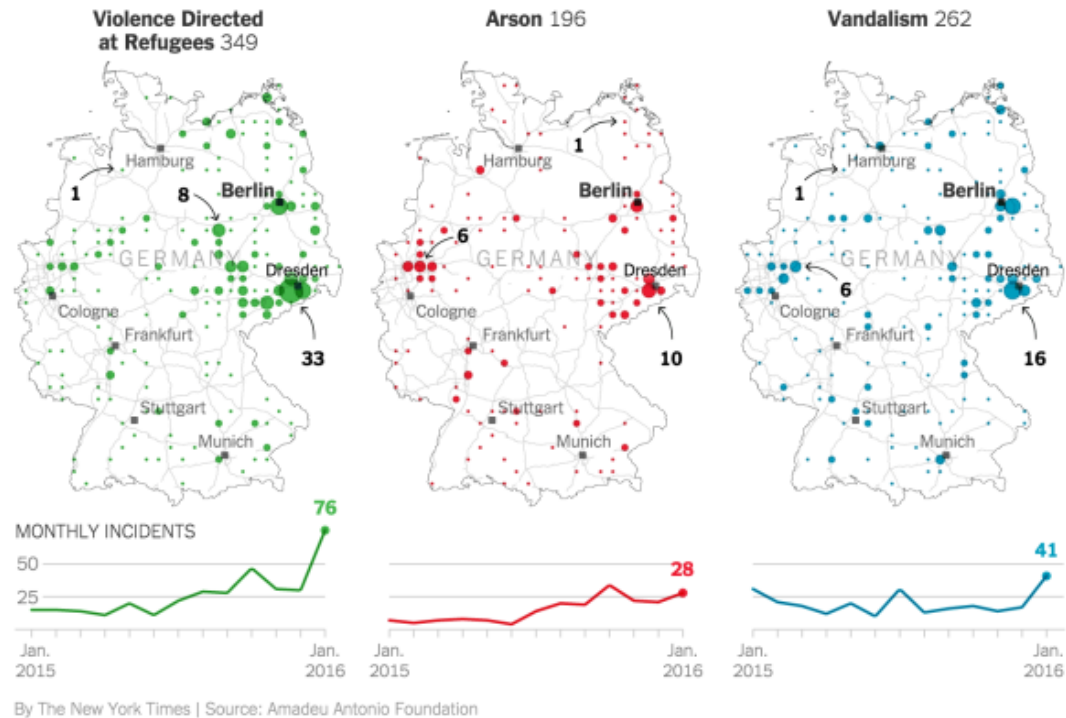
- What is Data Visualization?
- User Centered Design
- Visual Perception
- Criteria for Good Visualizations
- **Some examples**
- Resources

# Useful tricks



<https://blog.datawrapper.de/text-in-data-visualizations/>

# Make the outlier stands out

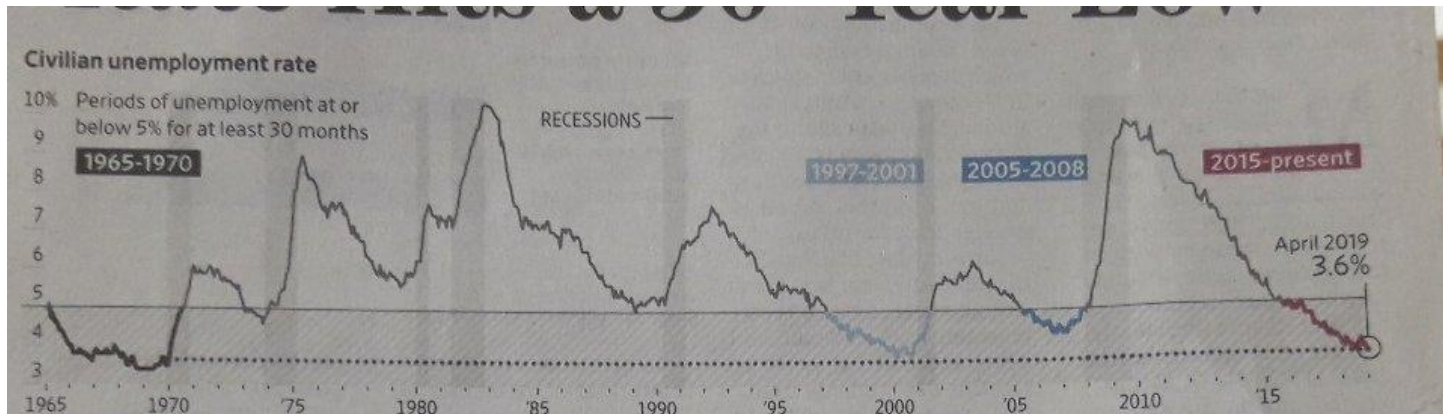


Hundreds of examples:

<https://www.visualisingdata.com/2016/03/little-visualisation-design/>



# Not emphasizing base line if not 0



Here's how this period of low unemployment, which began in 2015, stacks up to previous stretches.

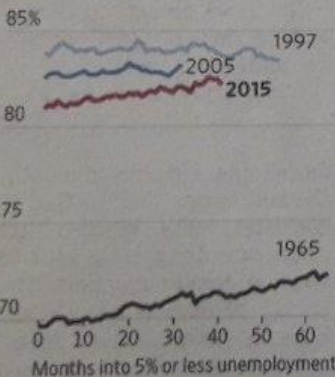
Fewer prime-age workers are in the labor force than in recent similar periods.

Real GDP growth has been steady compared with previous eras' stronger gains.

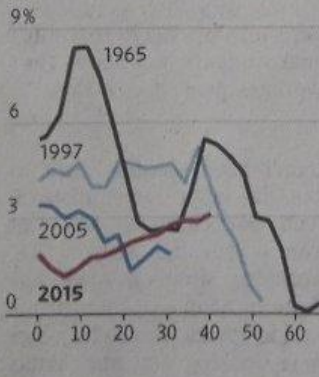
Hourly wage growth picked up but remains modest.

Inflation has been tame, preserving buying power.

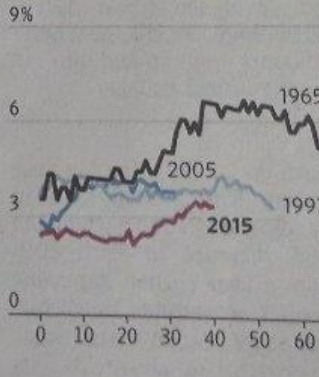
**Civilian labor-force-participation rate: 25 to 54 years**



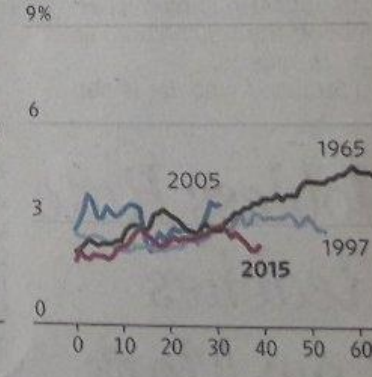
**Annual change in quarterly inflation-adjusted GDP**



**Annual change in average hourly earnings, nonsupervisory workers**



**Annual change in consumer-price index**



Note: Seasonally adjusted  
Source: Labor Department and Commerce Department via Federal Reserve Bank of St. Louis

# Graphics integrated into text

## The Chinese league is no longer seen as a 'retirement home', its clubs now attract many elite footballers in their prime years

In 2012 Didier Drogba and Nicolas Anelka were emblematic of a trend in prominent Europe-based players moving to China as their powers began to wane. Even last season Eidur Gudjohnsen and Robinho demonstrated that some still saw it as a comfortable place to see out their latter playing years. But this winter saw a clear shift, with clubs spending huge sums on players still at or yet to reach their peak years.

In the chart below, each circle represents an overseas player moving to China, sized by fee and positioned according to that player's age at the time. The red bars refer to the median age of all overseas signings that year. We also note the total calendar-year spend across all such signings

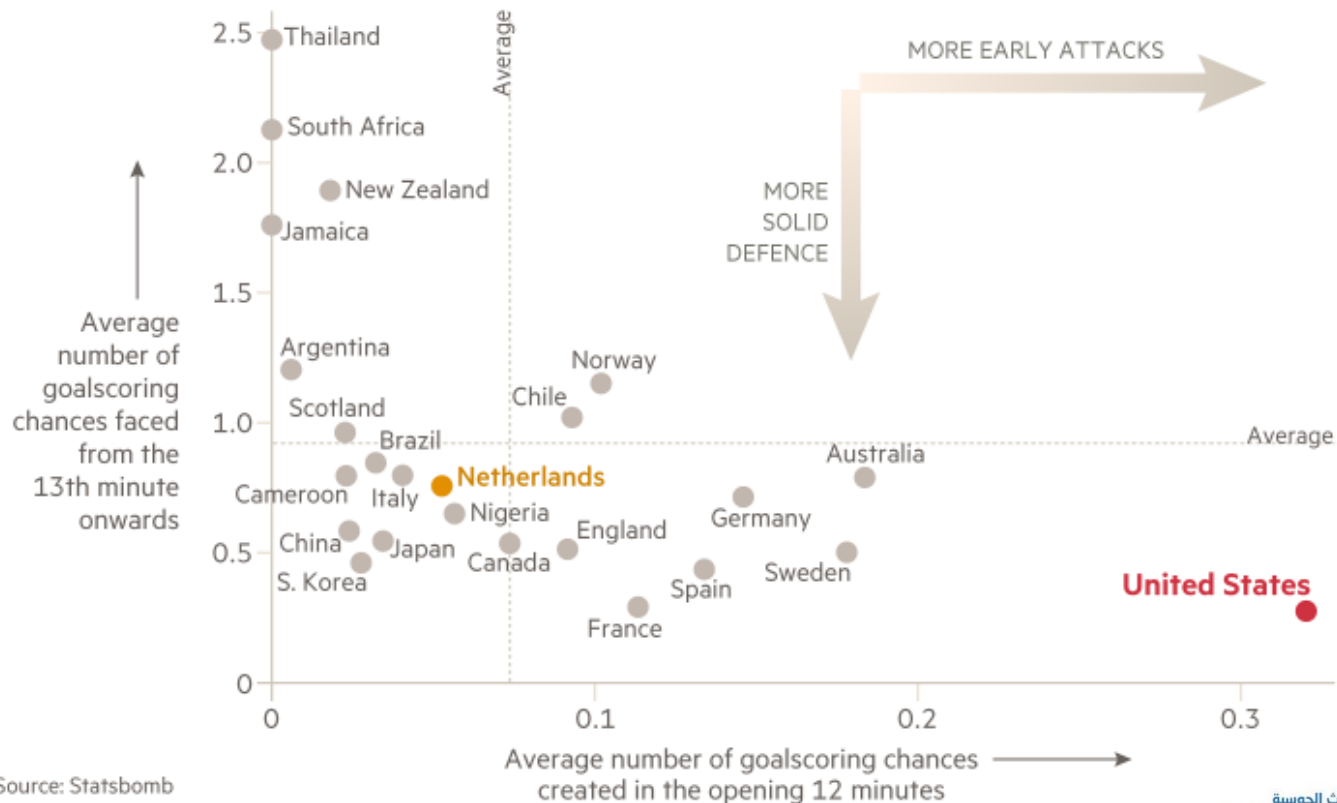


In the chart below, each circle represents an overseas player moving to China, sized by fee and positioned according to that player's age at the time. The red bars refer to the median age of all overseas signings that year. We also note the total calendar-year spend across all such signings

# Annotating to guide reading

The **US women's team** starts matches aggressively, taking the lead early, and then can defend as well as any other side

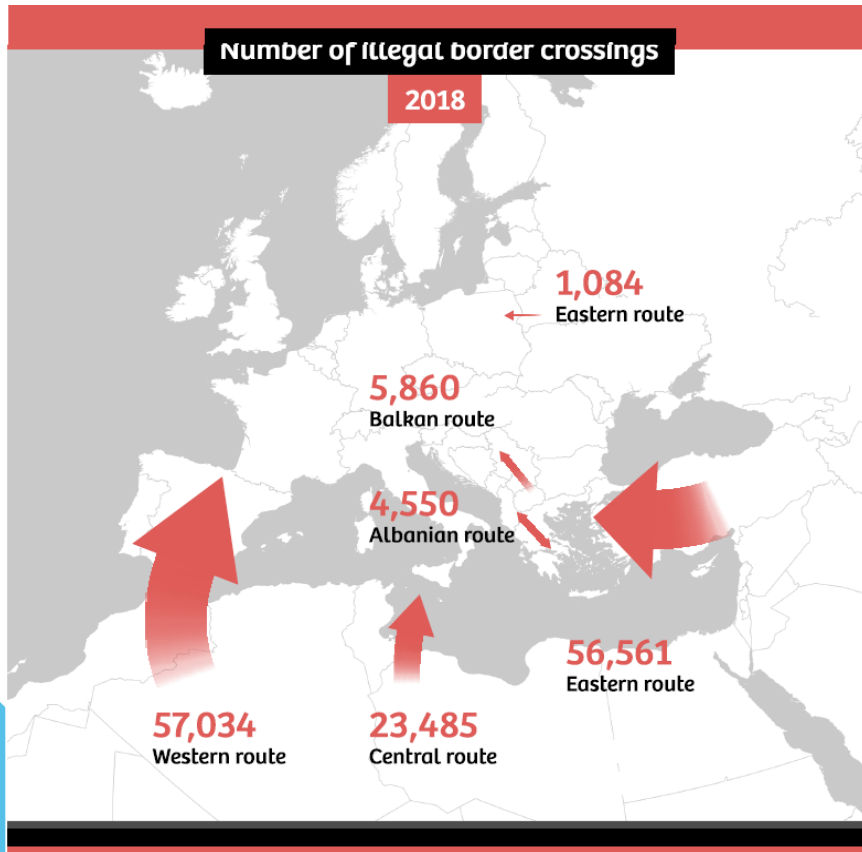
Rate of goalscoring chances created and conceded at the Women's World Cup 2019



Source: Statsbomb  
© FT

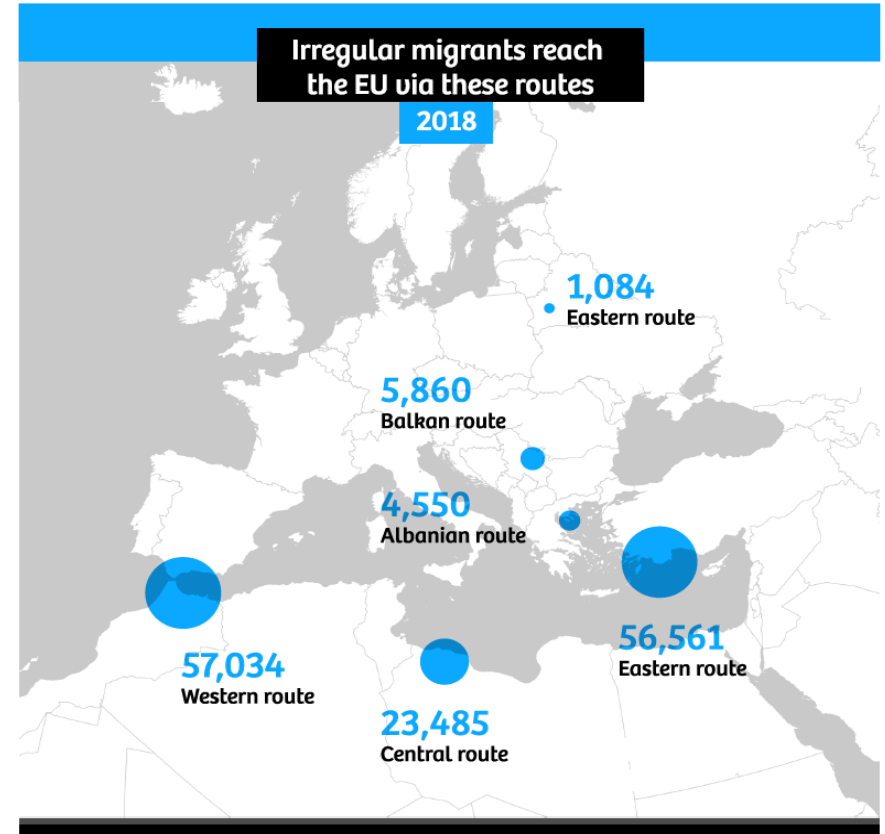
<https://www.ft.com/content/76ca29aa-9e57-11e9-9c06-a4640c9feebb>

# How design impact the message



## Anti-migrant design

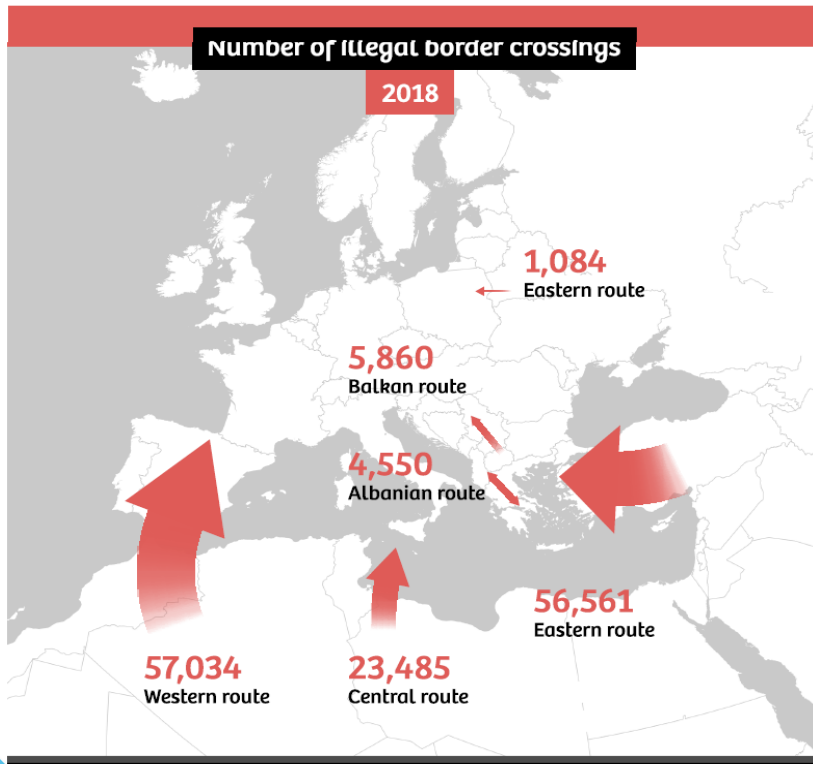
(show migration as an invasion flow of « illegal border crossing », use bloody color, large arrows)



## Pro-migrant design

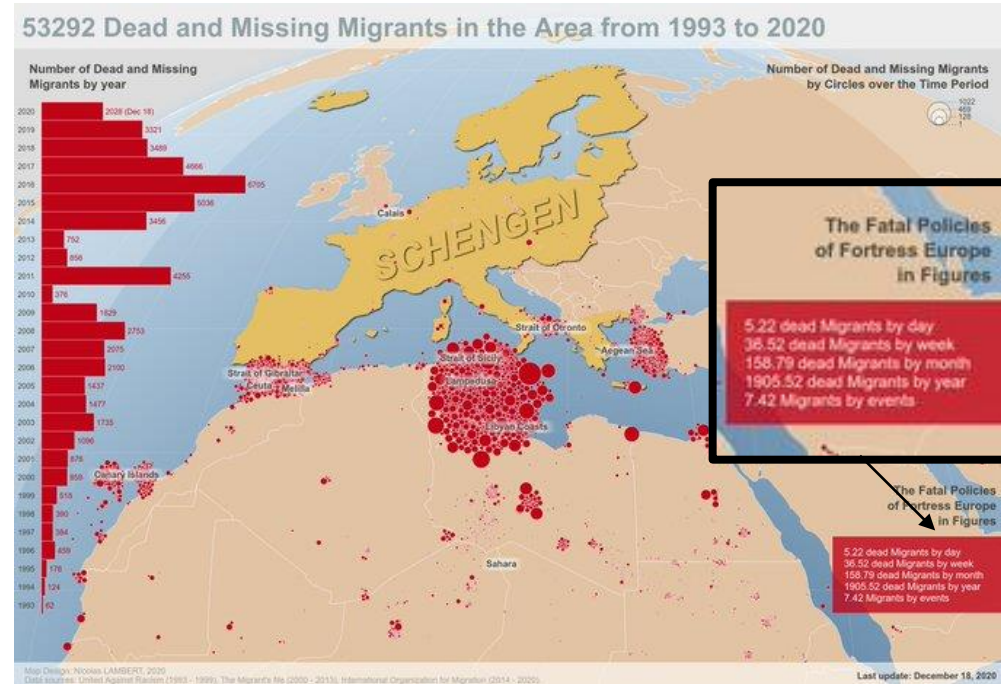


# It works both ways...



## Anti-migrant design

(show migration as an invasion flow of « illegal border crossing », use bloody color, large arrows)



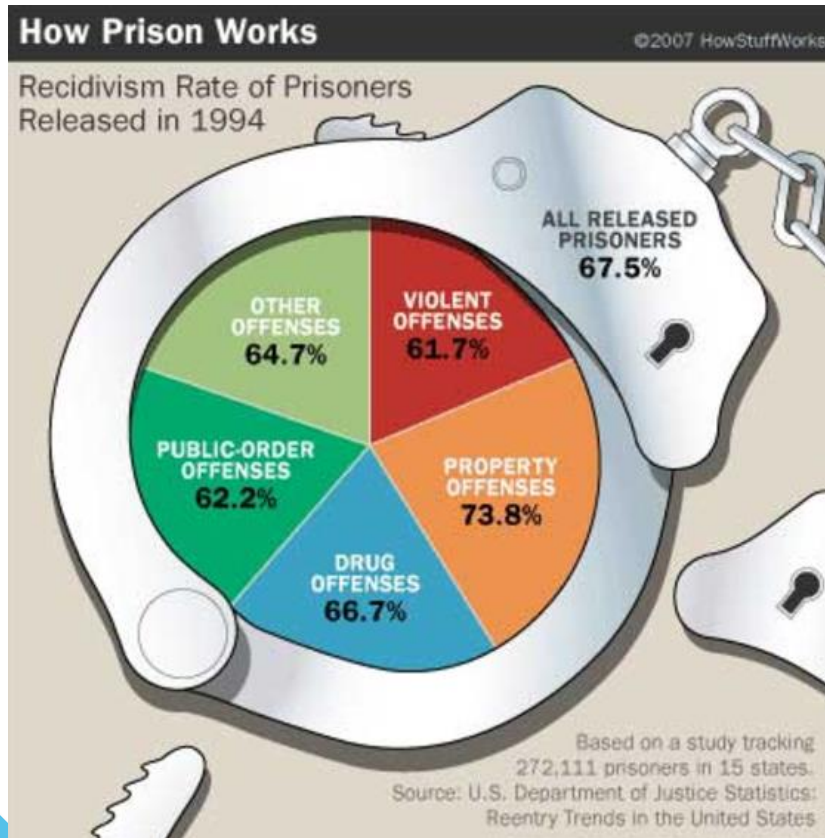
<https://analytics.huma-num.fr/Nicolas.Lambert/theborderkills/>

## Pro-migrant design

(show migration as number of death caused by « Fatal policies of Fortress Europe », use bloody color, large circles, number with 2 digits after dot (5.22 instead of 5) make them appear bigger)



# Pie chart offense



## Analysis

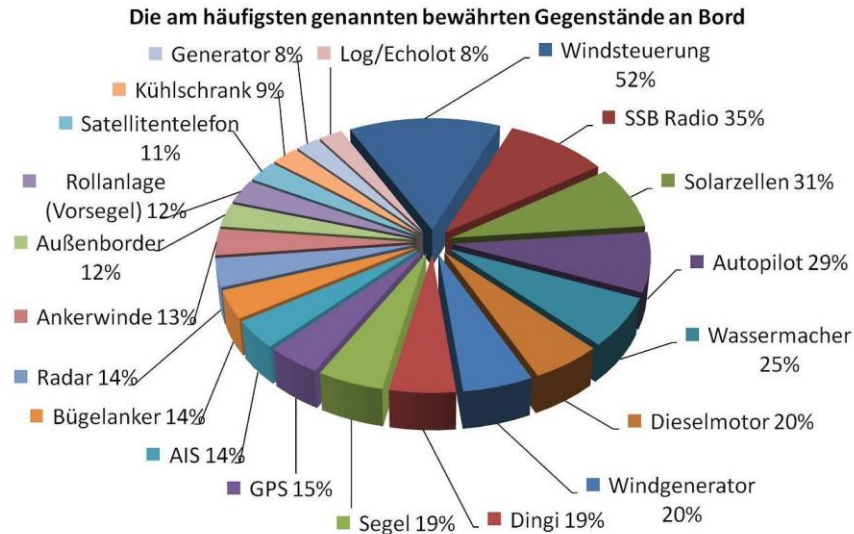
- Pie parts do not sum to 100%

## Advice

- Double-check your numbers
- Double-check numbers/data match with colors/graphics



# Pie chart revenge



## Analysis

- Shadow and 3D effects prevent easy comparison of pie segments
- Data are lost in unnecessary decor
- Too many data at once, difficult to figure out the global trend

## Advice

- Do not use fancy effects
- Show only data
- Group data by categories



# Bar chart offense

## Types of debt

The total owed by the average U.S. household, by debt type.



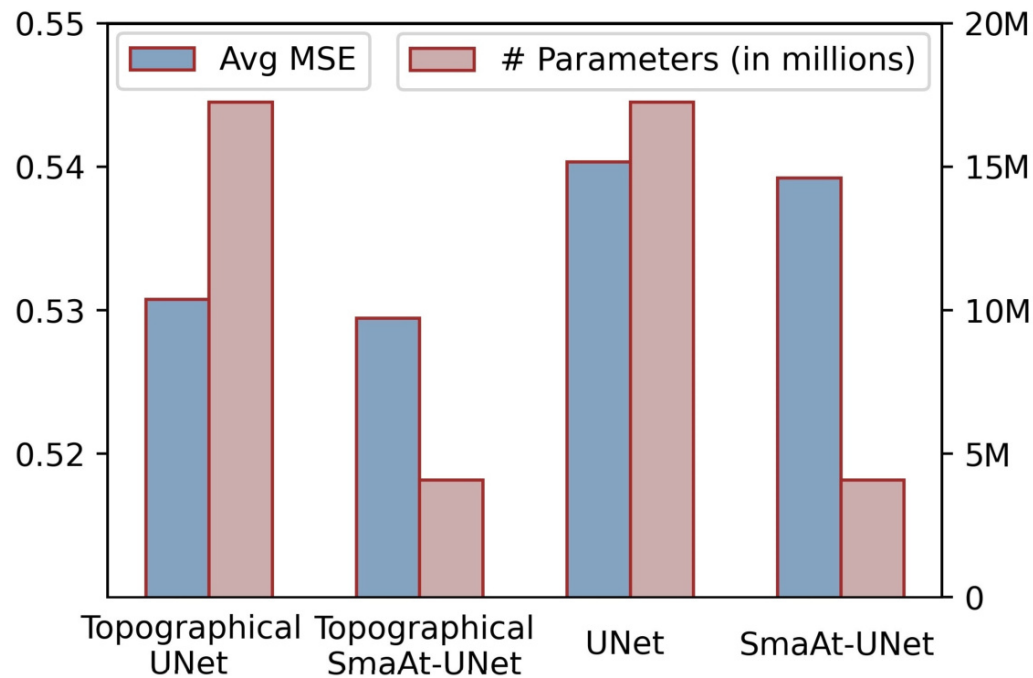
### Analysis

- Why the bars ordered that way?
- We look to understand why and never find out an answer because here order is arbitrary

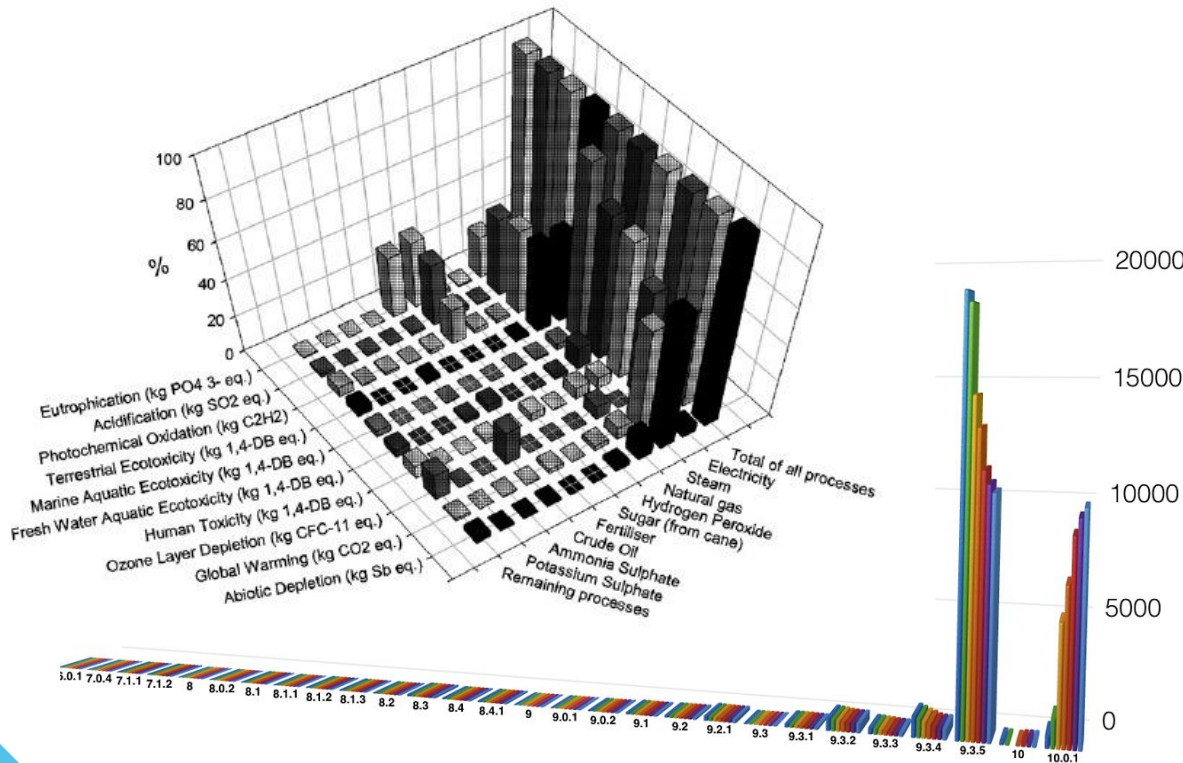
### Advice

- Remind that every detail ask our brain for an explanation that requires cognitive effort
- Do not overload your user brain, it has too many things to do already
- If order means something make it clear, otherwise order by value

# Bar chart offense 2



# No, 3D is not cool!



## Analysis

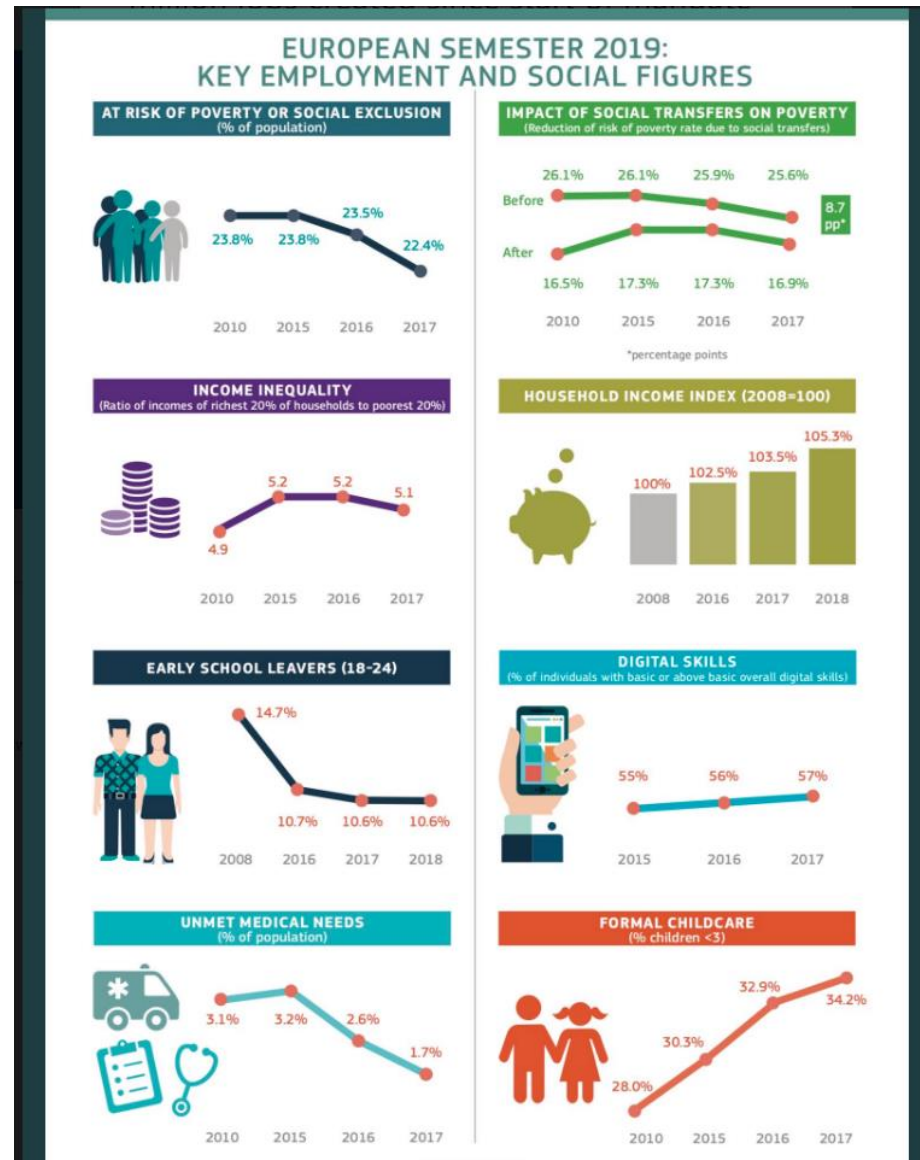
- Shadow and 3D effects prevent easy comparison of height of bars/columns
- Data are lost in unnecessary decor

## Advice

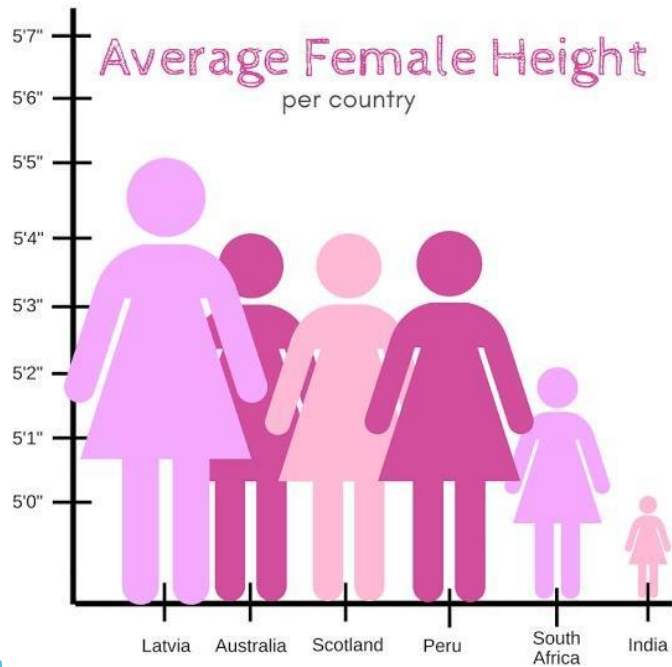
- Do not use fancy effects
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# Time is time

Broken time axis!

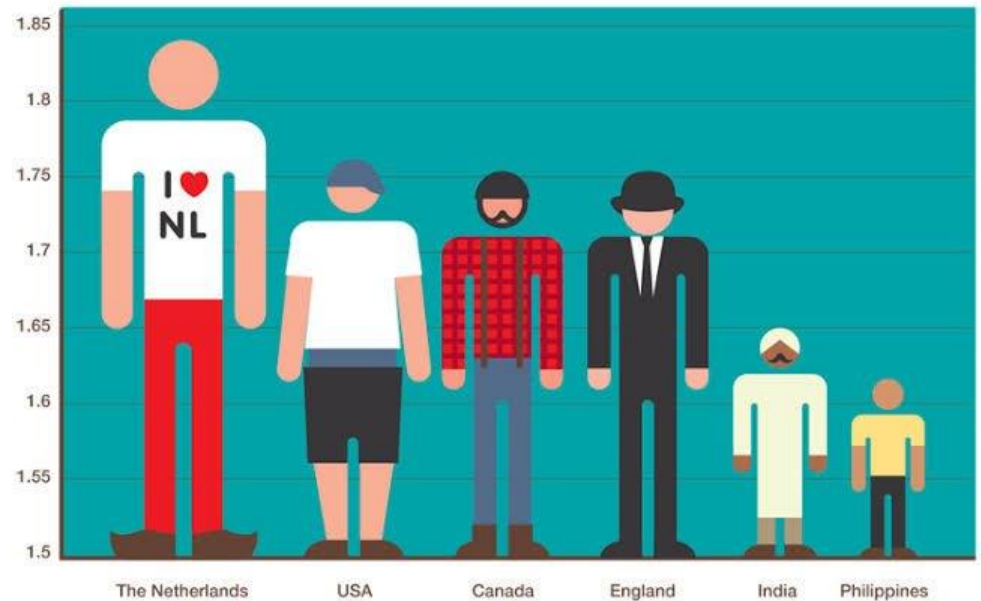


# Size matters!



### LOOKING DOWN ON THE REST OF THE WORLD

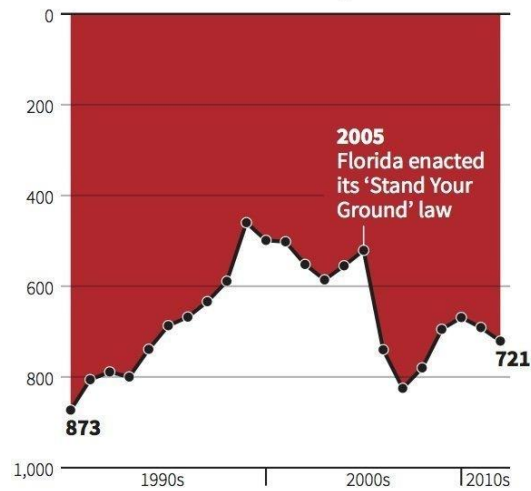
(Average male height in m)



# Bloody chart!

## Gun deaths in Florida

Number of murders committed using firearms



Source: Florida Department of Law Enforcement

C. Chan 16/02/2014

REUTERS

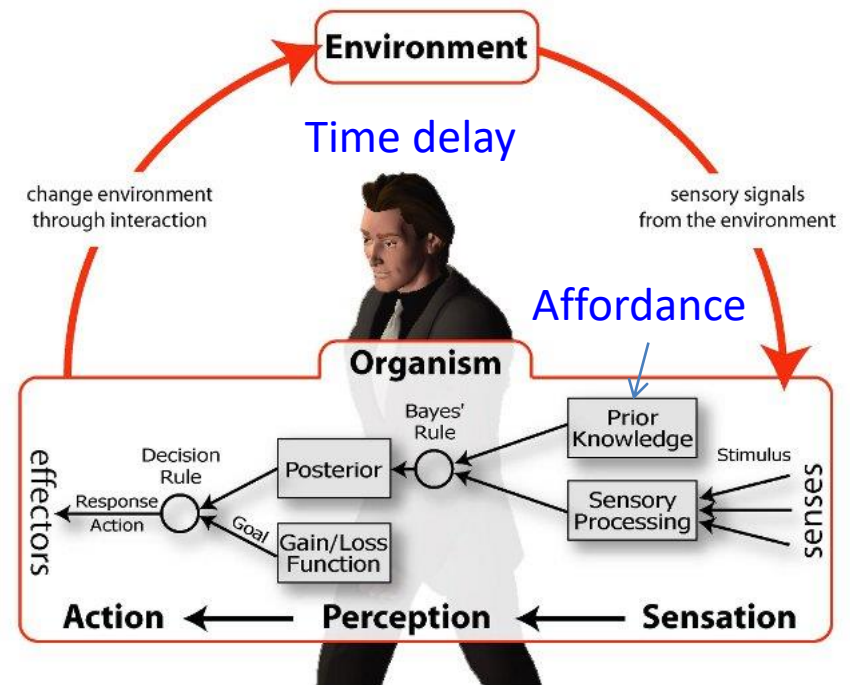


# Interactions

- Enactive knowledge is information gained through **perception–action interaction** in the environment

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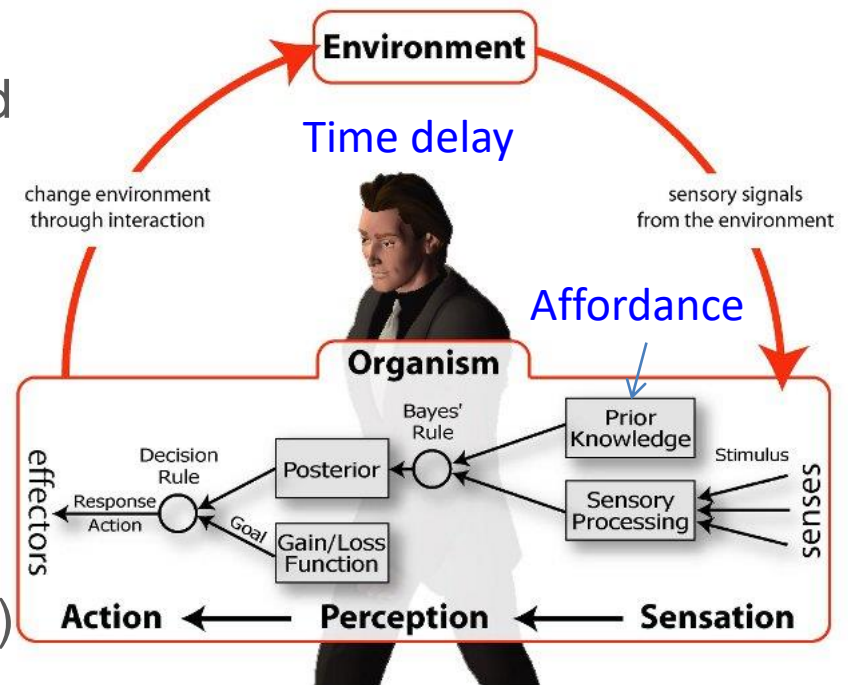
[http://www.uni-bielefeld.de/\(en\)/biologie/cns/](http://www.uni-bielefeld.de/(en)/biologie/cns/)



# Interactions

- Enactive knowledge is information gained through **perception–action interaction** in the environment

- Interaction enables detecting **cause and effect** to understand the environment
- Interaction is used to **tune the parameters** of the visualization
- Interaction requires **time perception** and **controllability** of the visualization (**affordance**)



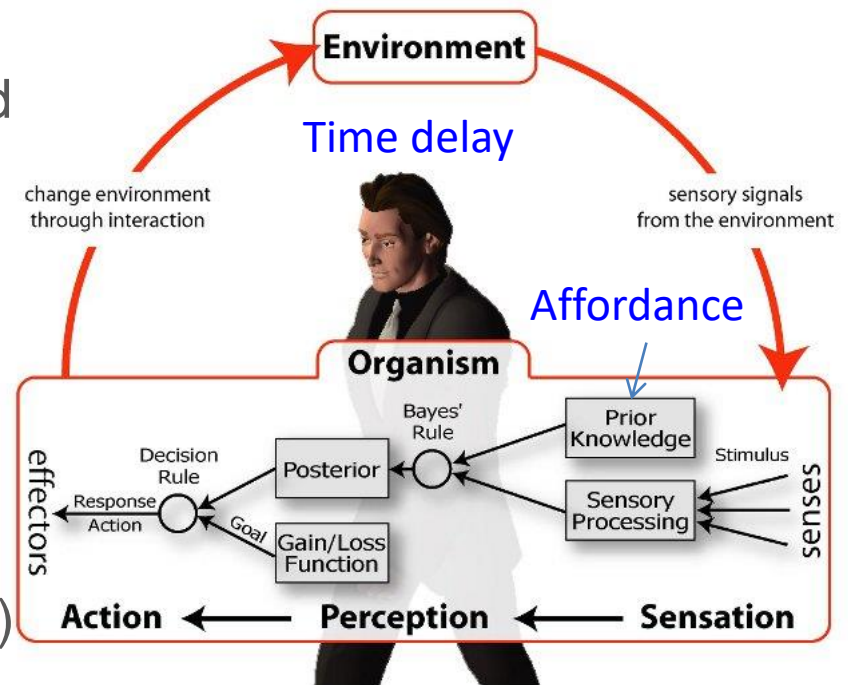
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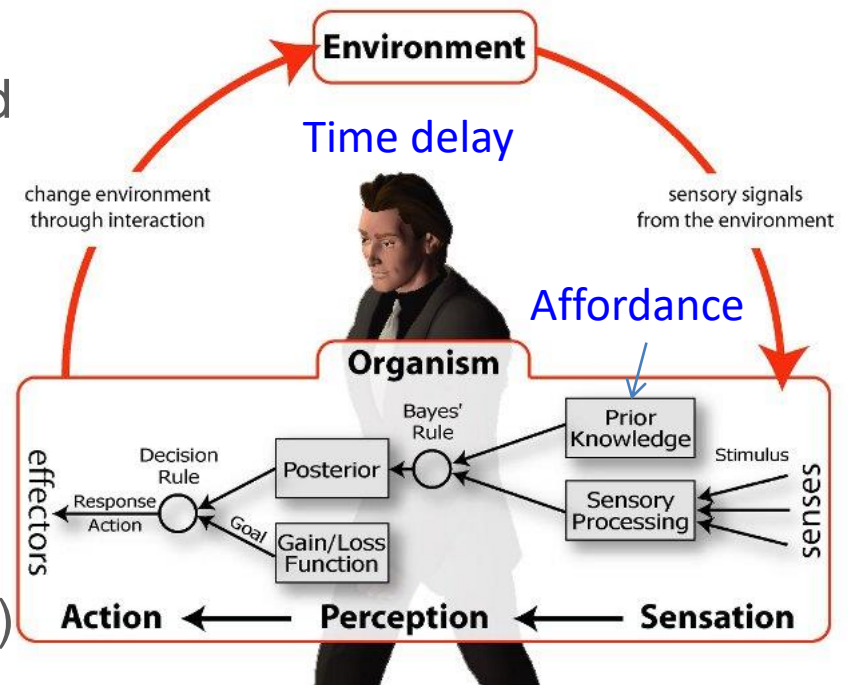
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# Interactions

- **Affordance**: design to ease discovery of possible actions

- *Buttons are designed to be pushed, so they trigger the desire to push and the pushing action*
- *Handles invite us to pull them...*

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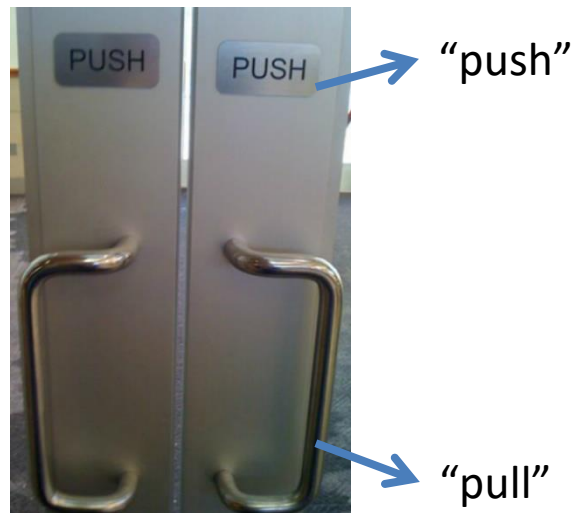




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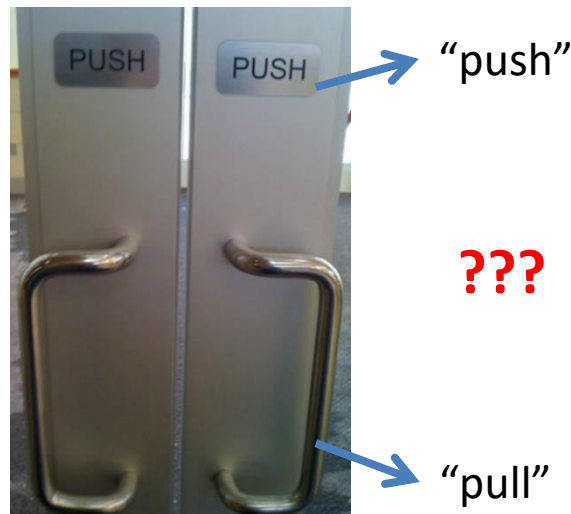
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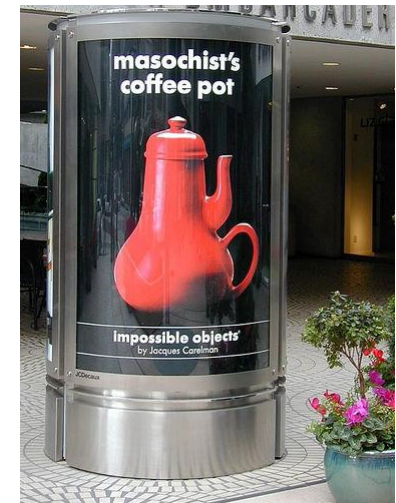
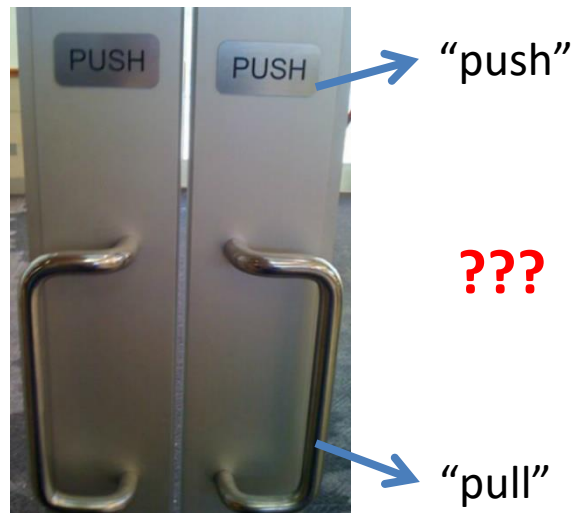
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- Two events perceived as a single one. Brain's neural activity cycle duration
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  - Action and stimulus less than 0.1s after it appear to be in **cause and effect relation**

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- ~**10 seconds:** complex action

- Time needed to complete an **interaction task** (zoom, use a slider, open select and click in a menu...)

# Consequences of response time

- **below a second** (continuity preserving latency)
  - appears **fully responsive** to user adjustments
  - allows **truly interactive** sessions
- **below a few seconds** (flow preserving latency)
  - users **maintain their focus**
  - computational pauses in the exploration **challenge interpretation**
- **above ten seconds** (attention preserving latency)
  - users **disengage from the task** to pursue other activities in parallel
  - highly **detrimental** to the interpretation process



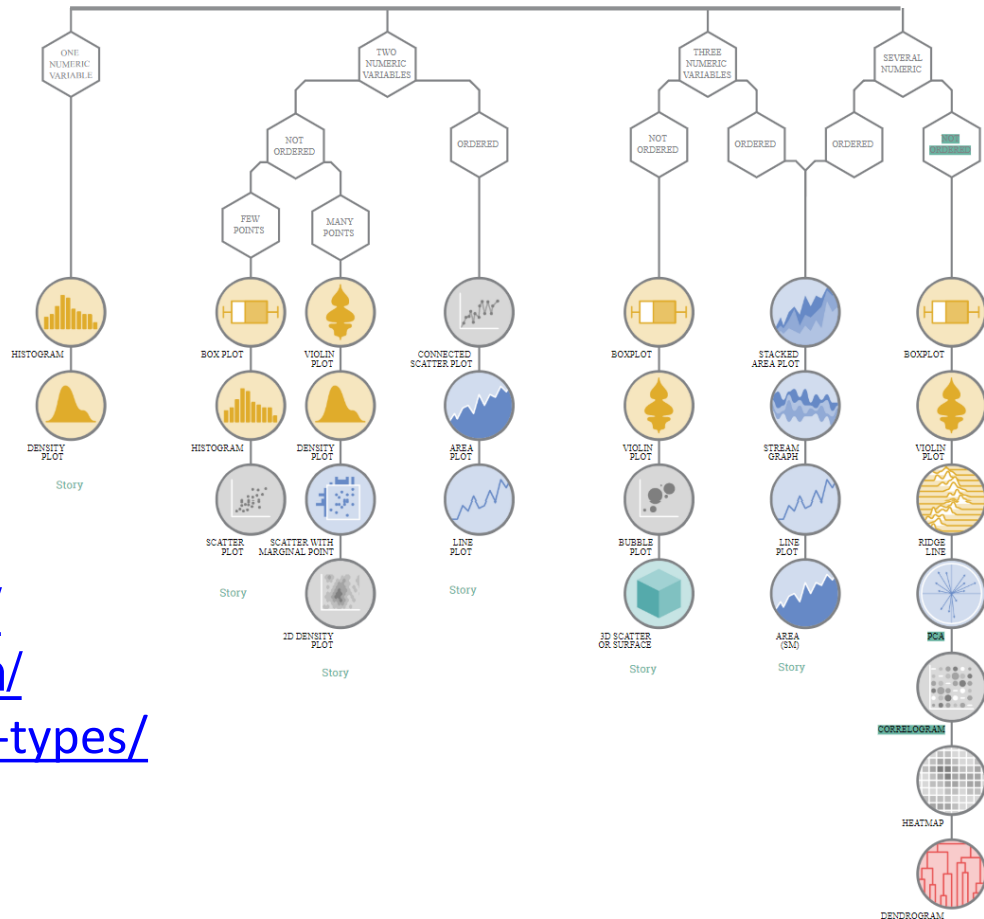
# Outline

- What is Data Visualization?
- User Centered Design
- Visual Perception
- Criteria for Good Visualizations
- Some examples
- **Resources**

# What makes a good graphical encoding

Some visual metaphors are more suited to some analytic tasks

<https://datavizproject.com/>  
<https://www.data-to-viz.com/>  
<https://datavizcatalogue.com/>  
<https://flowingdata.com/chart-types/>



# What chart to use

- <https://blog.datawrapper.de/guide-what-to-consider-when-creating-tables/>
- → Line charts: <https://t.co/ZoUUjd2gP6>
- → Area charts: <https://t.co/eXlOoIXTLI>
- → Pie charts: <https://t.co/dR4inn22D2>
- → Choropleth maps: <https://t.co/sMsSJc2qey>
- → Stacked columns: <https://t.co/fJK1Ftsx5P>
- → Colors: <https://t.co/XYSSu4KVGE>
- <https://gramener.github.io/visual-vocabulary-vega/#>
- Vis guidelines:  
[http://experception.net/Franconeri\\_ExperCeptionDotNet  
DataVisQuickRef.pdf](http://experception.net/Franconeri_ExperCeptionDotNet>DataVisQuickRef.pdf)
- D3 gallery: <https://www.d3-graph-gallery.com/>

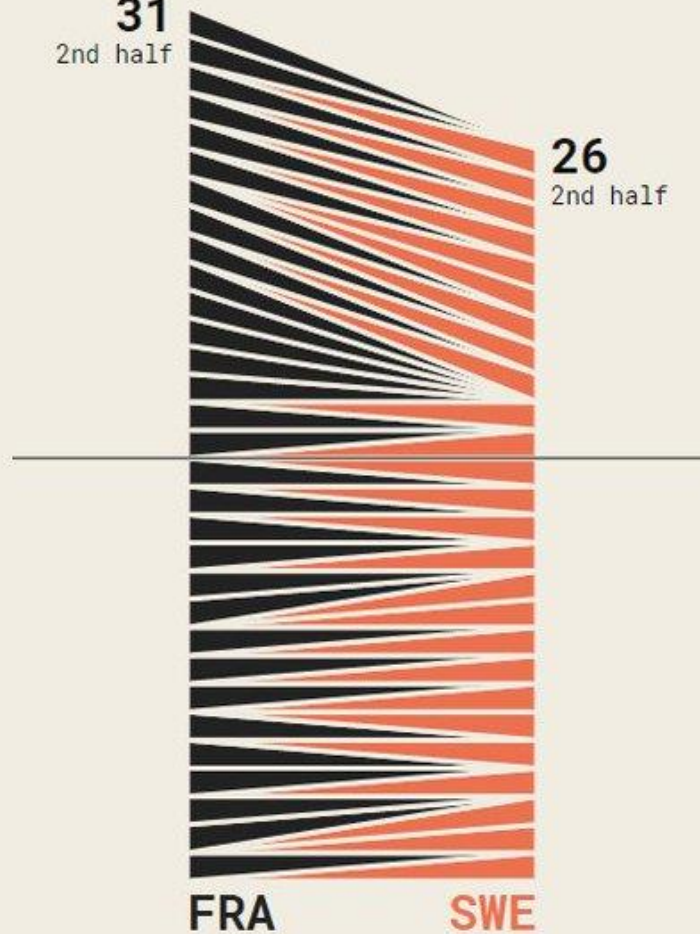
**Thank you!**

**maupetit@hbku.edu.qa**

Women's Handball World Championship, Quarter Finals  
15 December 2021, Spain

**31**  
2nd half

**26**  
2nd half



data source: ihf.info

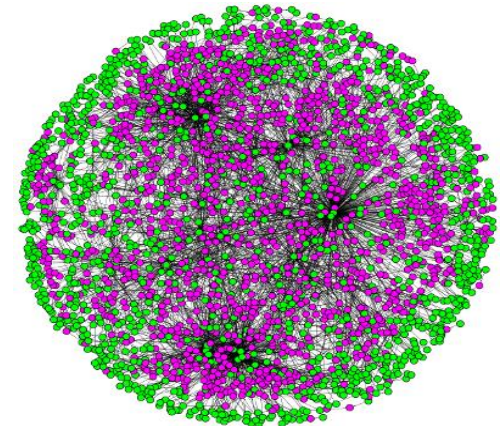
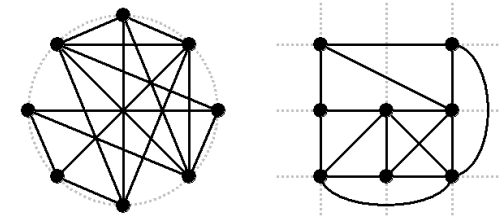
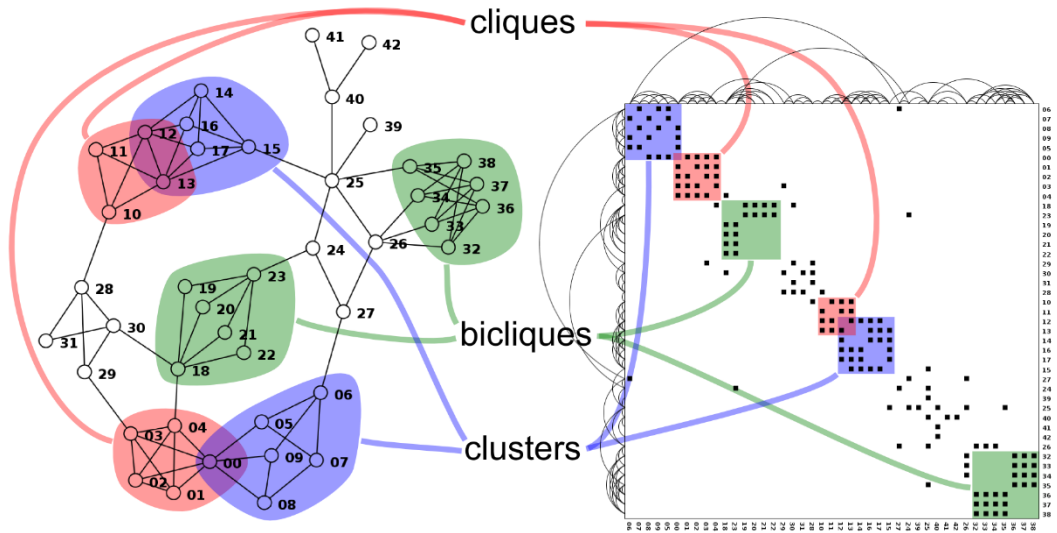
created with PL•T PARADE

<https://twitter.com/i/status/1471443312032759819>



# Networks

- Adjacency matrix vs node-link diagram



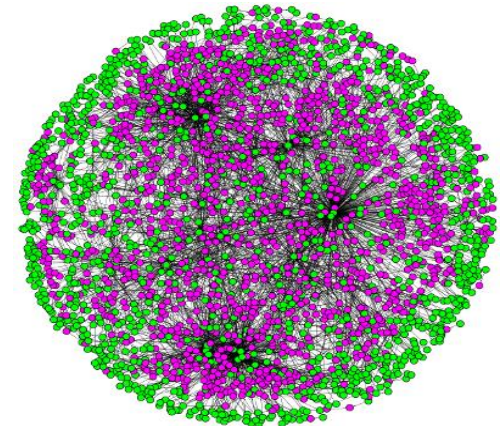
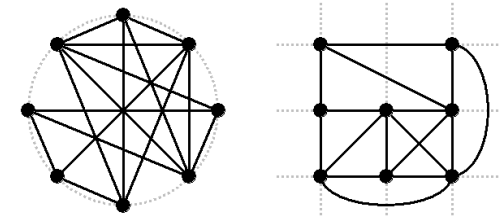
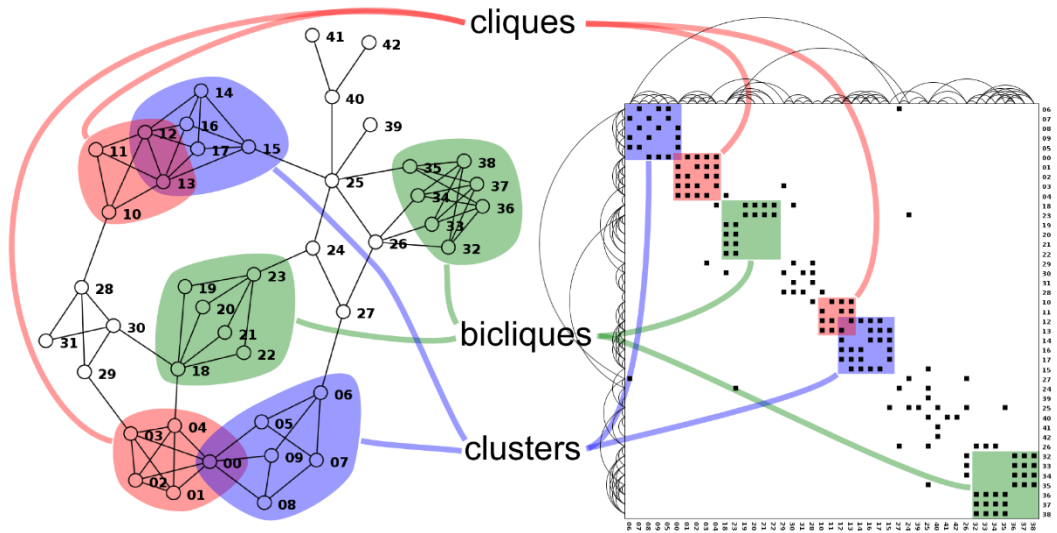
**Node-Link**  
**Nodes can overlap**  
**Links can cross**  
**Need less space**  
**Easy to follow paths**

**Adjacency Matrix**  
**No node overlap**  
**No link crossing**  
**Need more space (sparse matrix)**  
**Difficult to follow paths**

*E. coli* metabolic network visualized with Cytoscape [source: kavrakilab.org]

# Networks

- Adjacency matrix vs node-link diagram



## Node-Link

- Nodes can overlap**
- Links can cross**
- Need less space**
- Easy to follow paths**

## Adjacency Matrix

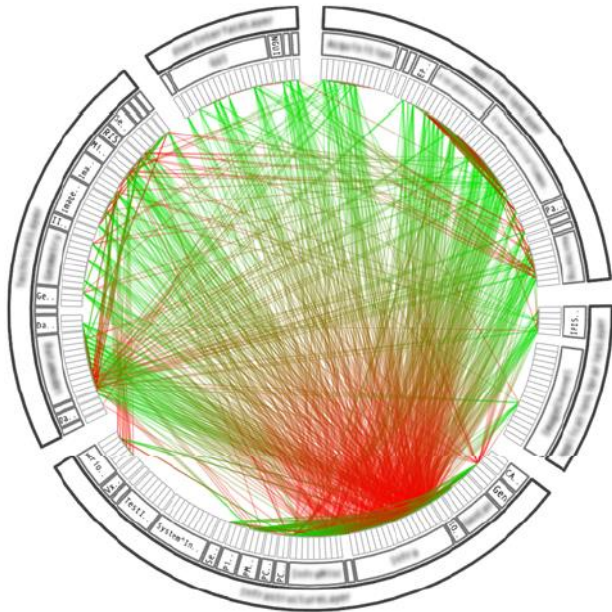
- No node overlap**
- No link crossing**
- Need more space (sparse matrix)**
- Difficult to follow paths**

*E. coli* metabolic network visualized with Cytoscape [source: kavrakilab.org]



# Networks

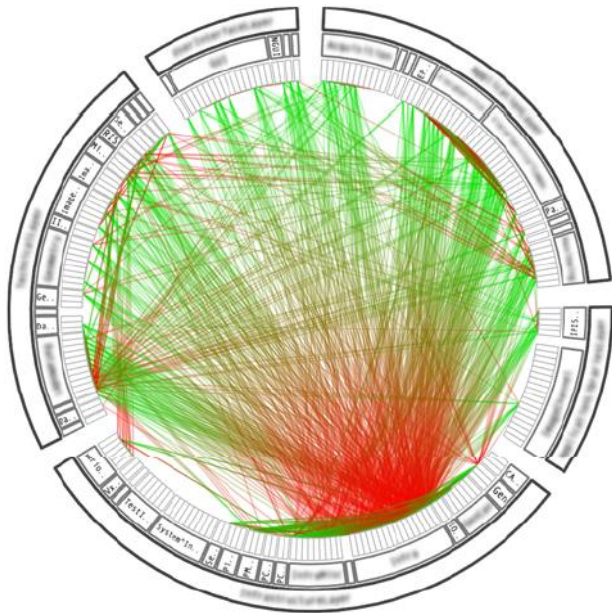
- Edge bundling



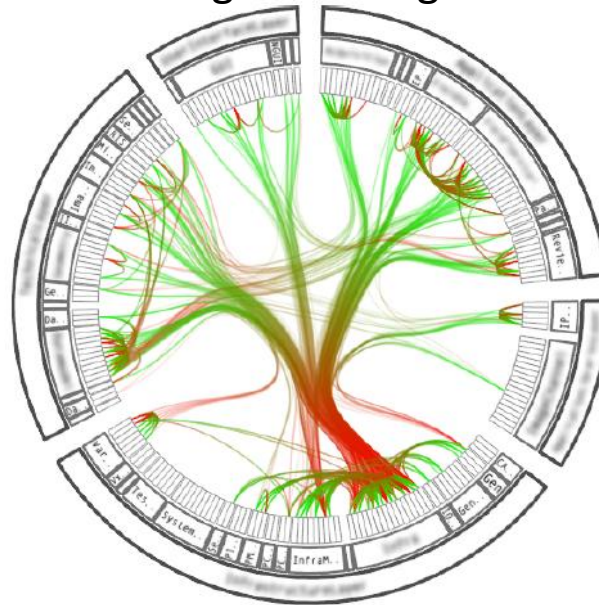


# Networks

- Edge bundling

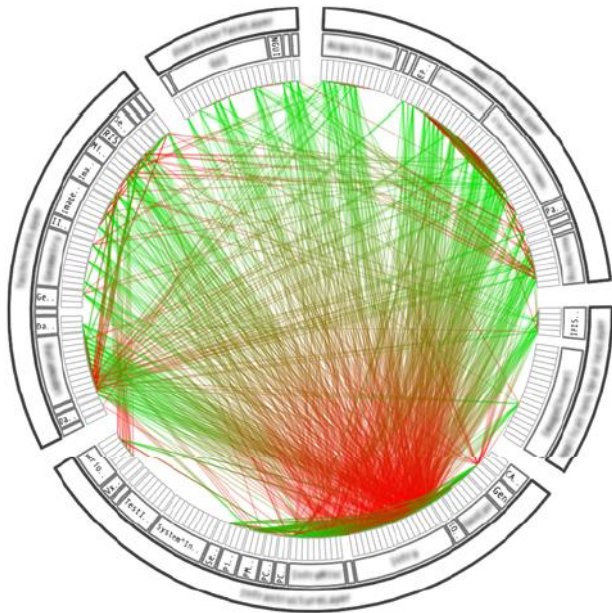


Edge bundling

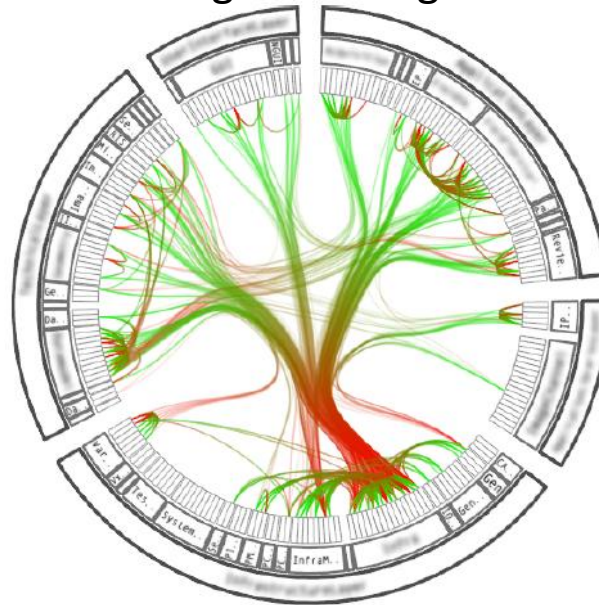


# Networks

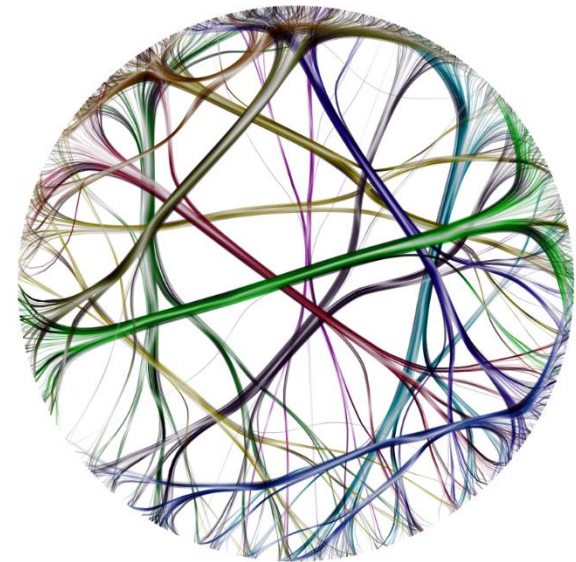
- Edge bundling



Edge bundling



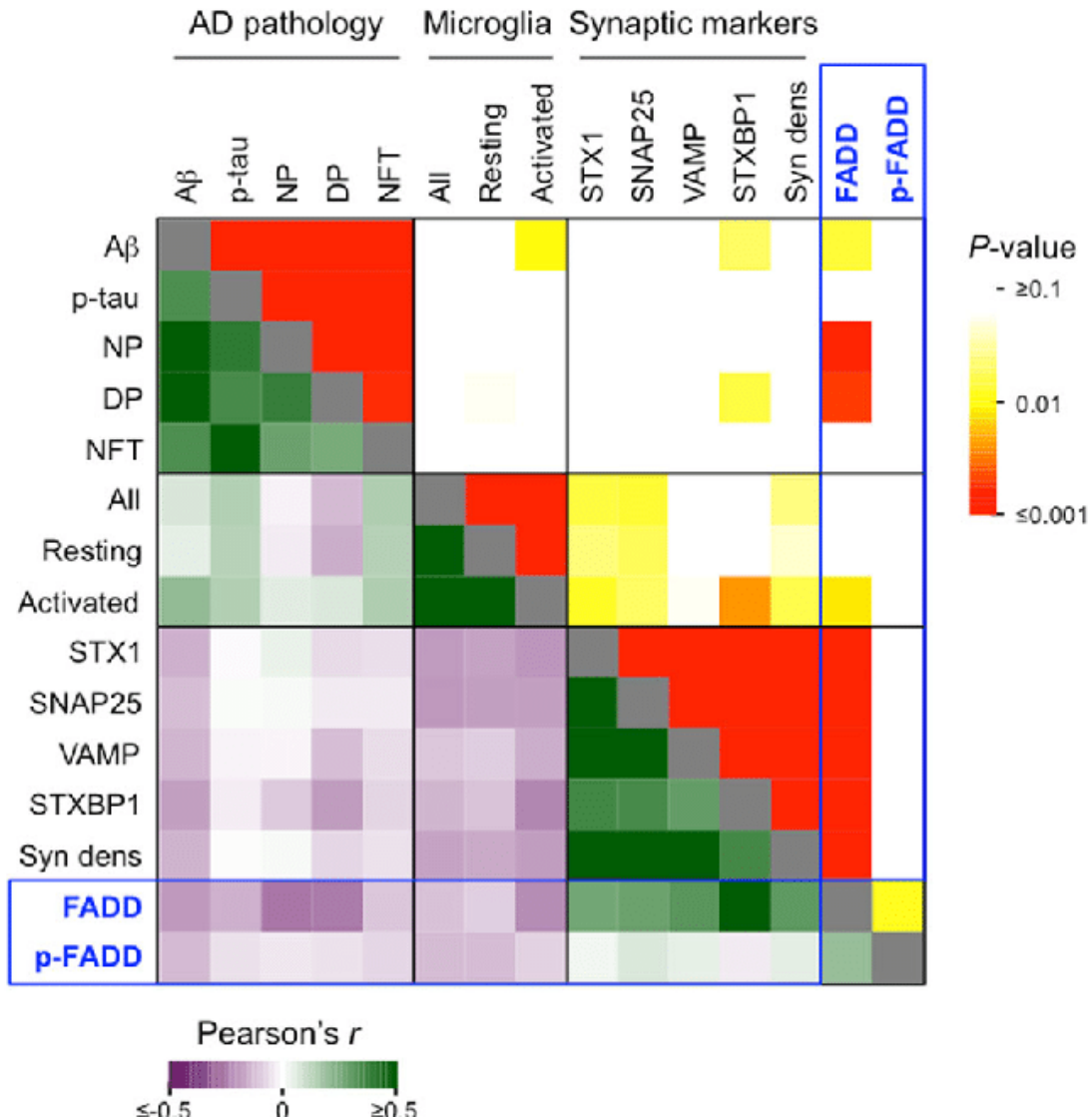
Improved rendering



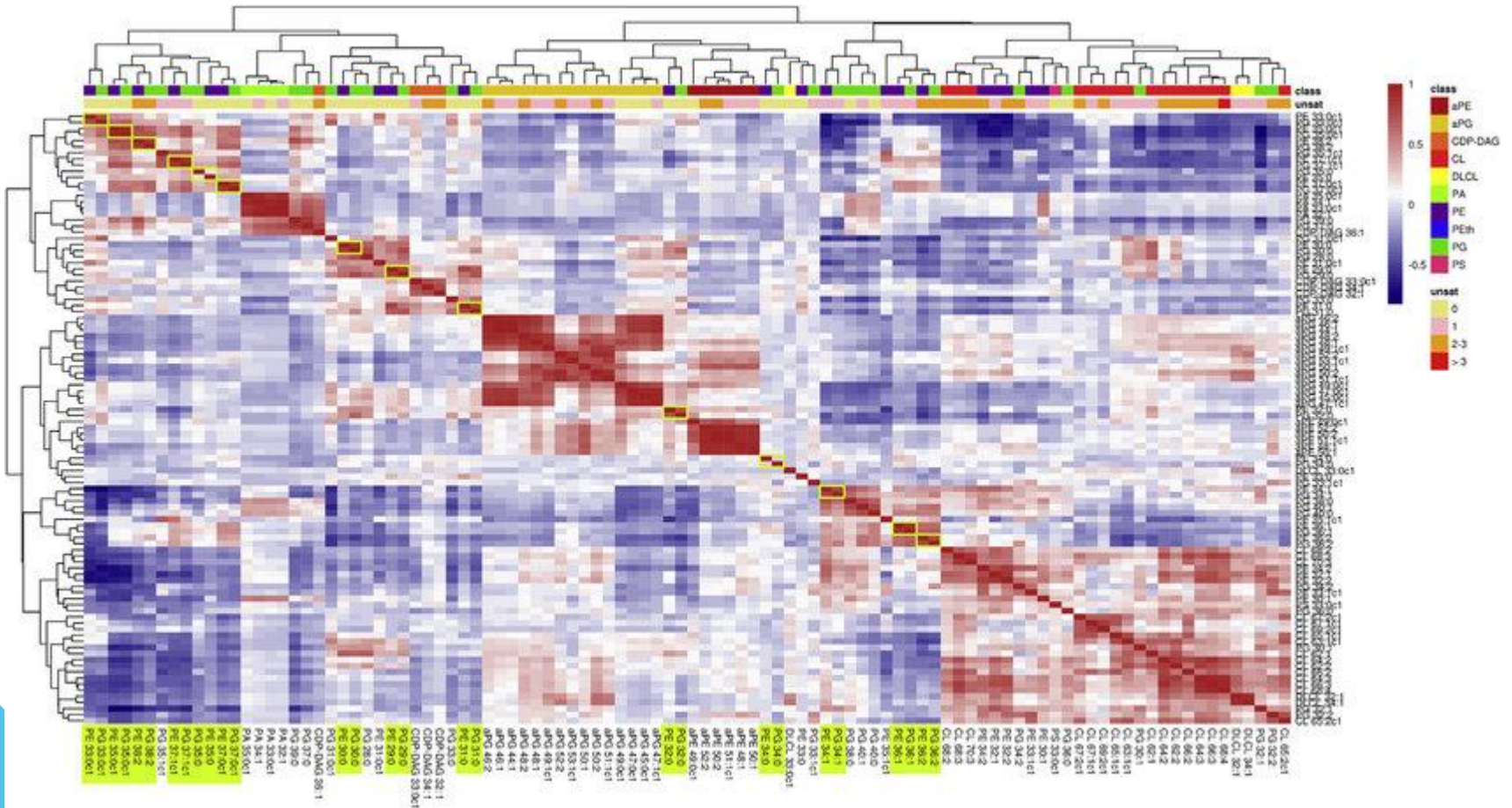
# Heatmap



# Heatmap

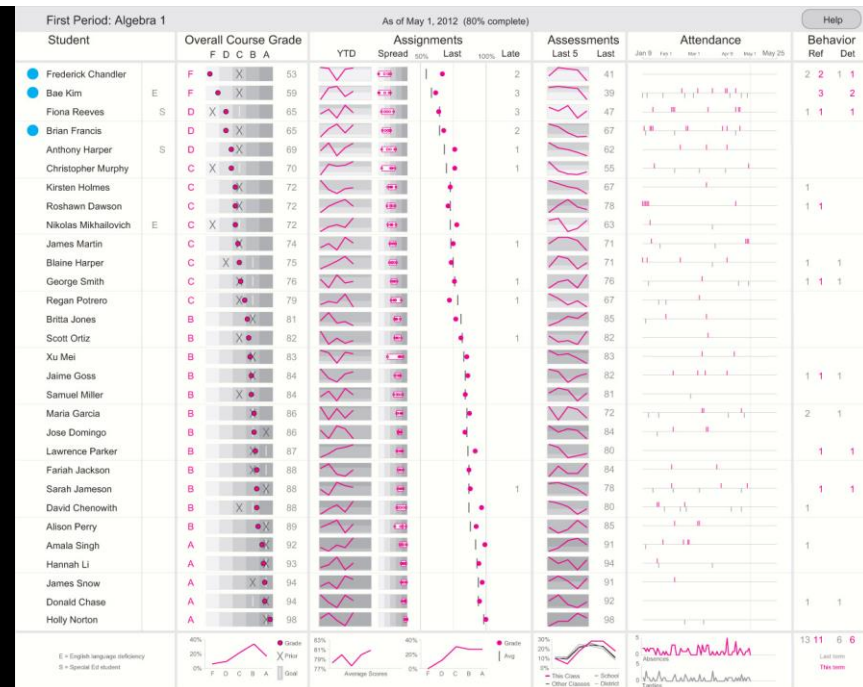


# Heatmap



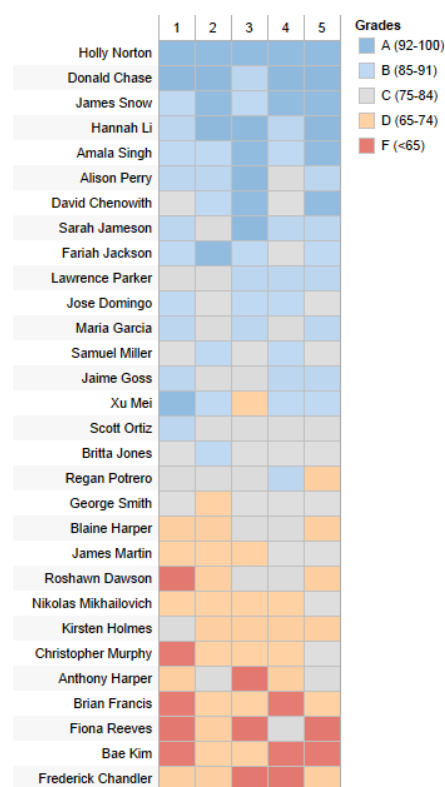
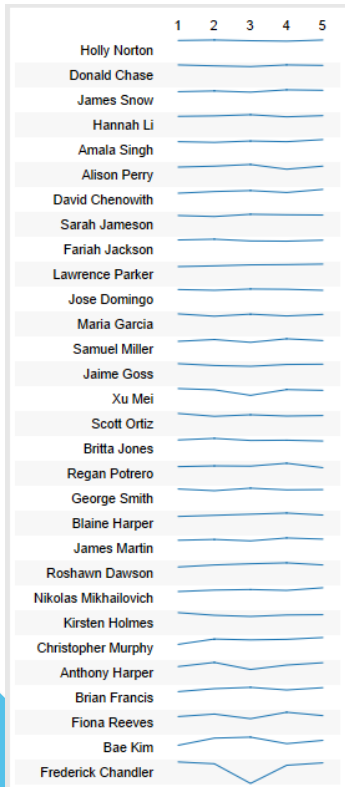
# Sparklines

Student Name	Assignment 1 Score	Assignment 2 Score	Assignment 3 Score	Assignment 4 Score	Assignment 5 Score
Alison Perry	87%	91%	98%	78%	91%
Amala Singh	90%	87%	93%	90%	99%
Anthony Harper	65%	79%	55%	70%	78%
Bae Kim	46%	68%	71%	51%	61%
Blaine Harper	69%	73%	77%	81%	74%
Brian Francis	57%	66%	70%	62%	69%
Britta Jones	81%	87%	79%	80%	77%
Christopher Murphy	55%	73%	70%	72%	78%
David Chenowith	81%	88%	92%	84%	97%
Donald Chase	97%	93%	90%	97%	95%
Fariah Jackson	89%	92%	85%	84%	88%
Fiona Reeves	61%	69%	54%	75%	64%
Frederick Chandler	71%	65%	0%	60%	68%
George Smith	78%	72%	81%	75%	76%
Hannah Li	91%	93%	98%	89%	94%
Holly Norton	98%	100%	97%	95%	100%
Jaime Goss	88%	81%	78%	85%	86%
James Martin	71%	74%	69%	79%	75%
James Snow	91%	94%	89%	99%	97%
Jose Domingo	87%	84%	89%	88%	84%
Kirsten Holmes	79%	70%	66%	71%	72%



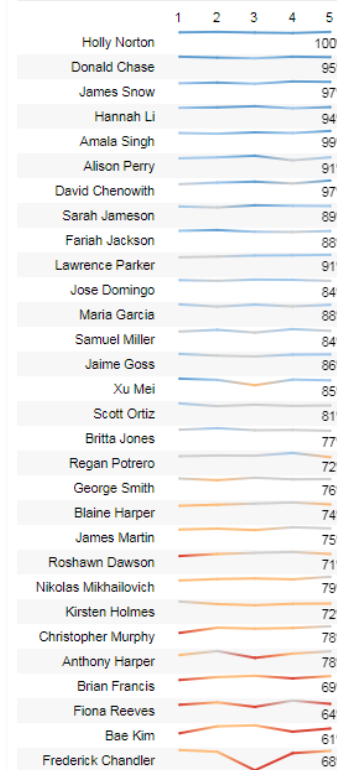
<http://www.perceptualedge.com/blog/?p=1466>

# Redundant encoding

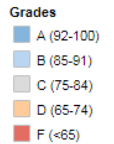
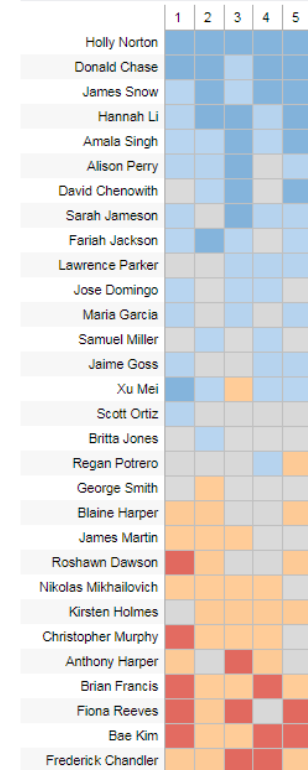


## Sparklines vs. Highlight Tables

Sparklines



Highlight Table

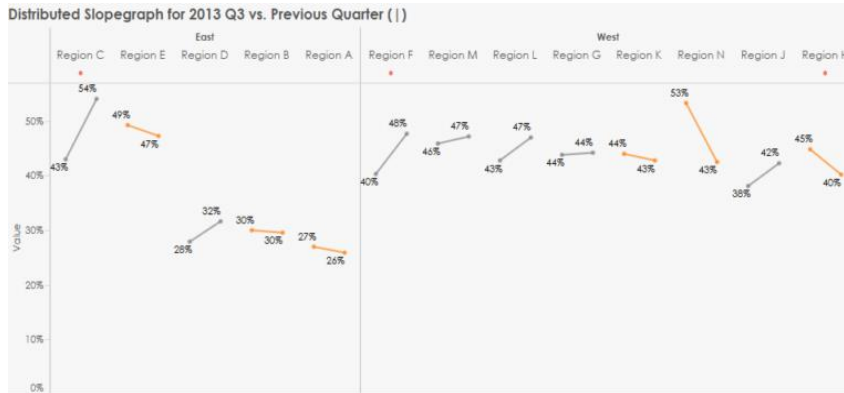


<https://www.datarevelations.com/sparklines-schmarklines.html>

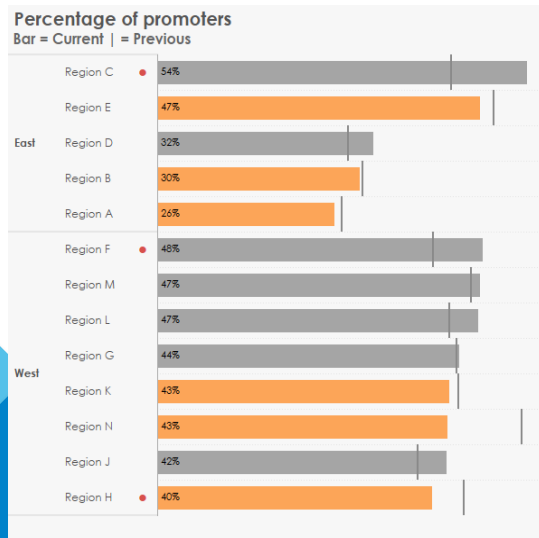
# Comparison – Comet Charts

- <https://www.datarevelations.com/showing-now-versus-then-consider-a-comet-chart.html>

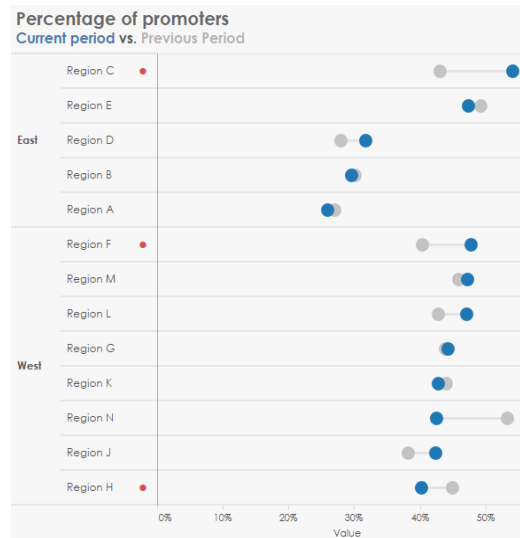
## Slope graph



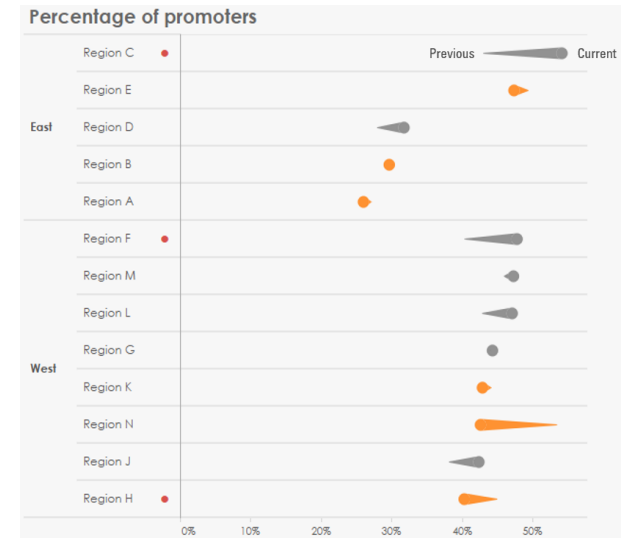
## Bar chart



## Gap chart



## Comet chart

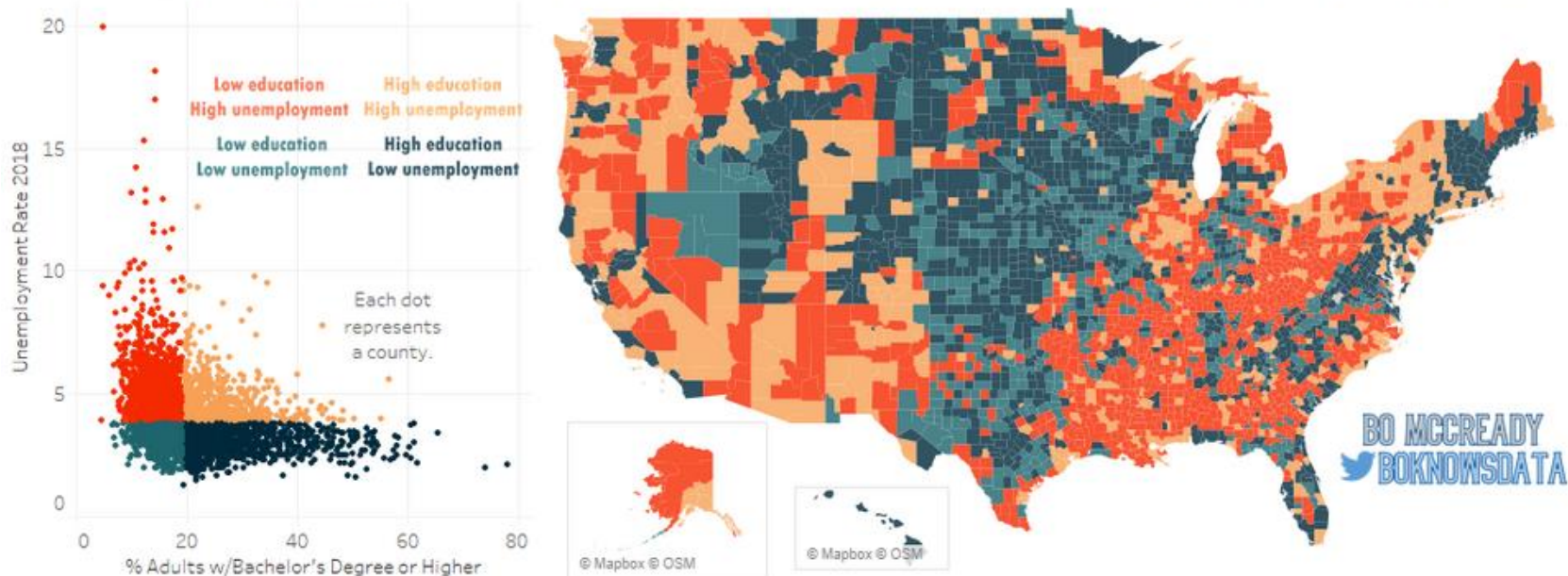




# Scatterplot as a color scale

## EDUCATION AND UNEMPLOYMENT

This map shows counties in the US colored into four categories based on educational attainment (as measured by the percent of adults 25+ with a bachelor's degree or higher 2013-2017) and unemployment rate (based on 2018 unemployment) relative to the median for all counties. Data comes from the USDA Economic Research Service.



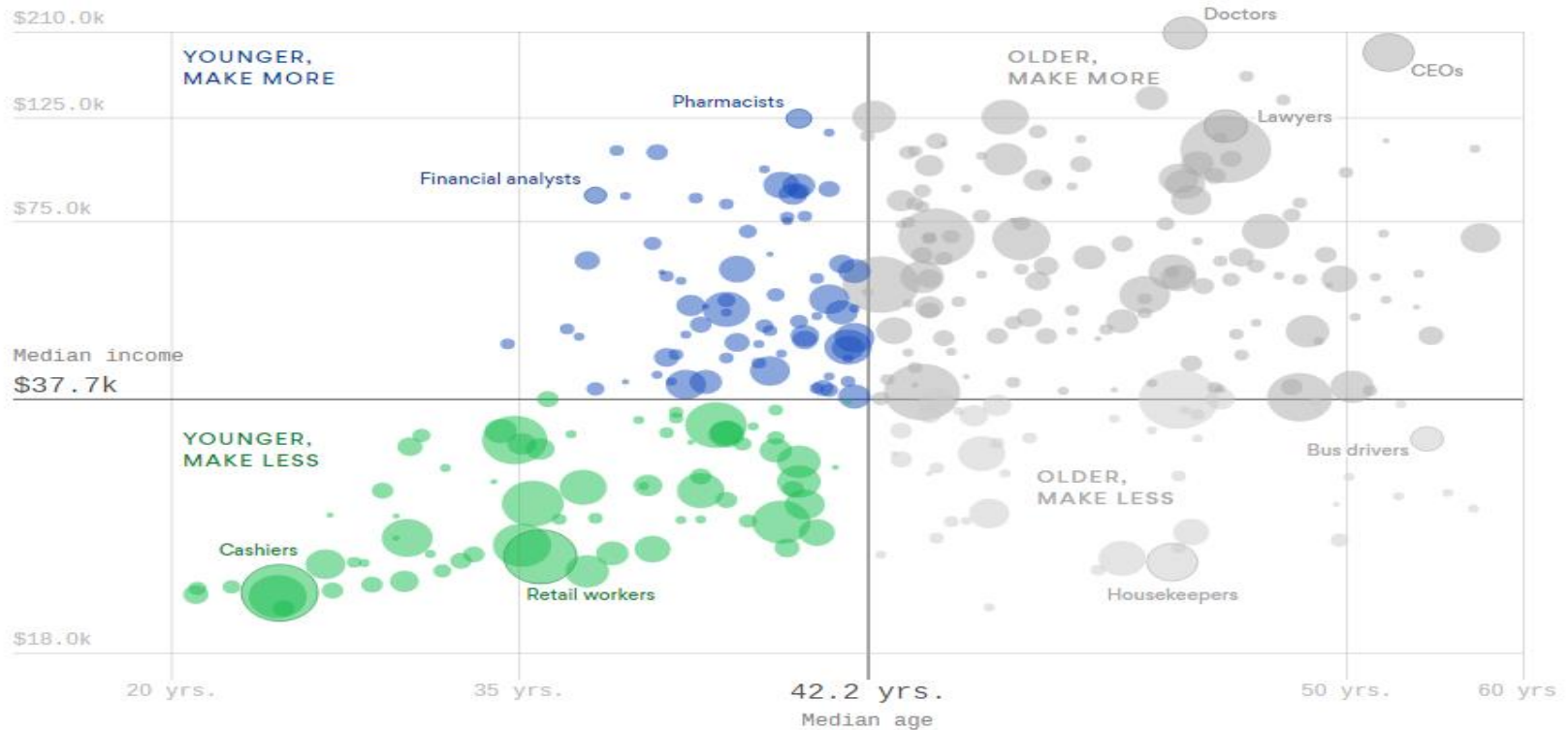
# Scatterplot

Show median = remind decision tree

<https://www.axios.com/the-oldest-and-youngest-jobs-in-the-us-millennials-d9738704-4c84-4208-8f15-8d997db170ac.html>

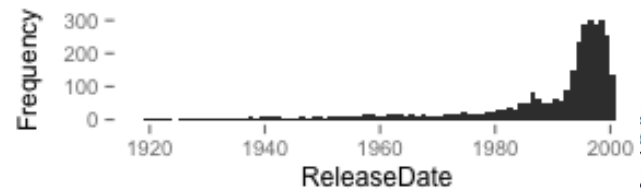
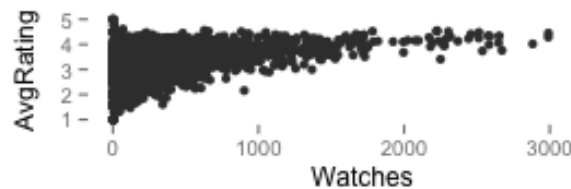
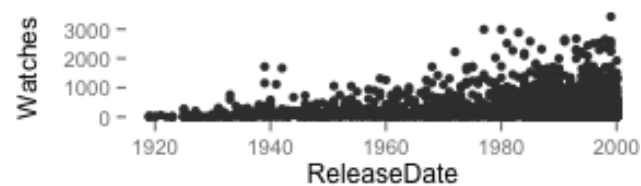
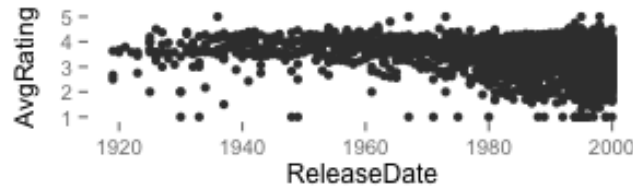
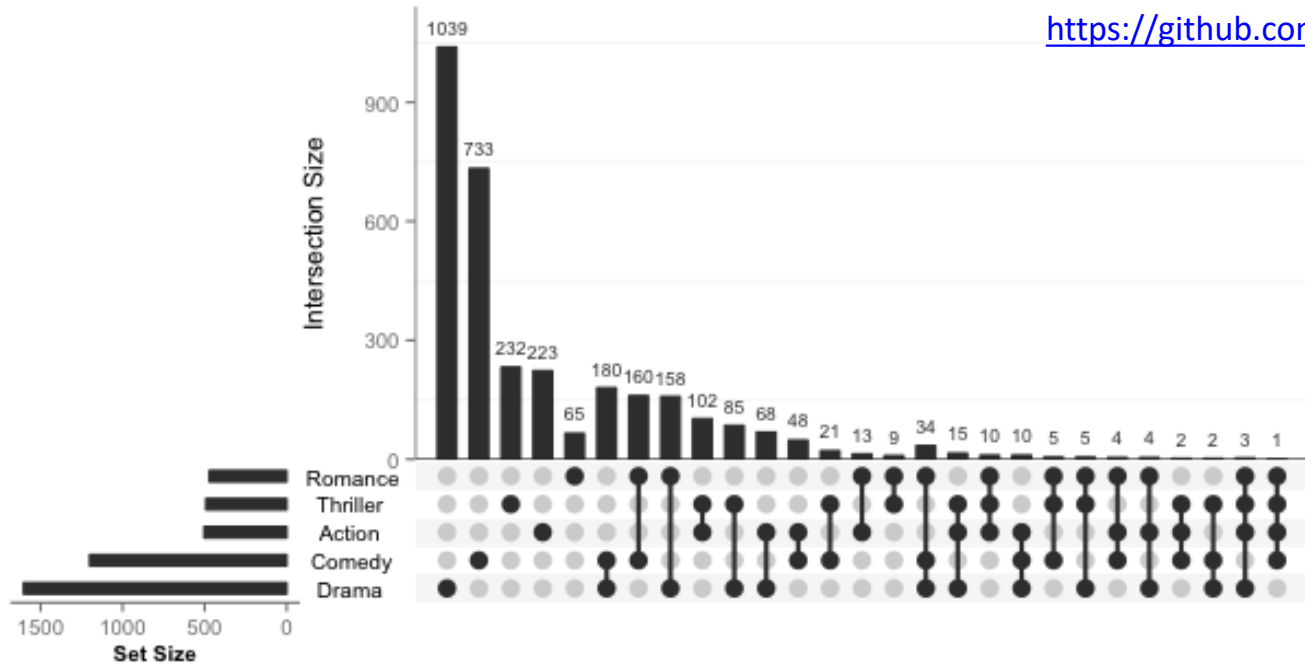
## U.S. occupations by median income and age

- Bubble size is number of workers
- 👆 Hover on circles for company information



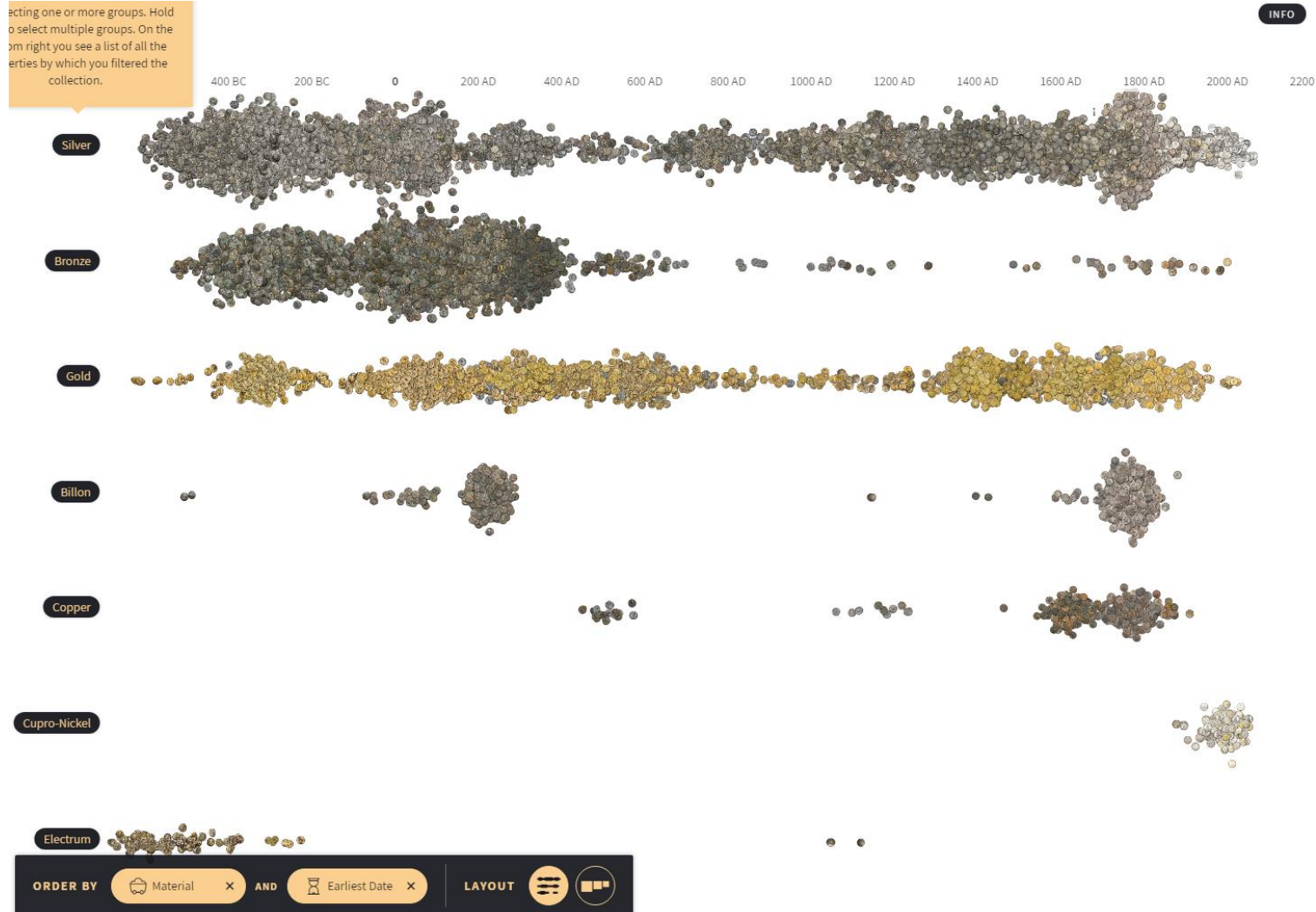
# View all sets combinations (powerset)

<https://github.com/hms-dbmi/UpSetR>



# When design meets data viz

- <https://uclab.fh-potsdam.de/coins/>
- <https://uclab.fh-potsdam.de/projects/coins/>



# The Ladder of Abstraction

- Have a look at

<http://worrydream.com/LadderOfAbstraction/>

# Time and space

<http://survey.timeviz.net/>

The screenshot displays the 'The TimeViz Browser' website. The page title is 'The TimeViz Browser: A Visual Survey of Visualization Techniques for Time-Oriented Data' by Christian Tominski and Wolfgang Aigner. The main content is a grid of 112 small thumbnail images representing different visualization techniques. On the left side, there are several filter panels:

- # of Techniques:** 112
- Search:** A search input field.
- Data:**
  - Frame of Reference: Abstract (ON), Spatial (ON)
  - Number of Variables: Univariate (ON), Multivariate (ON)
- Time:**
  - Arrangement: Linear (ON), Cyclic (ON)
  - Time Primitives: Instant (ON), Interval (ON)
- Visualization:**
  - Mapping: Static (ON), Dynamic (ON)
  - Dimensionality: 2D (ON), 3D (ON)
- Our book:** A section for a book related to the browser.

The browser window shows several open tabs, including 'survey.timeviz.net', 'ResearchGate', 'Social Network', and 'Download Fre...'. The taskbar at the bottom shows several open applications, including 'vizionejnp', 'VizsterVisualizingOnl...', 'ZAME\_InteractiveLar...', 'CS3724-iv.ppt', 'Uvic\_viztools\_Asimil...', and 'MatrixExplorerUnSys...'. The system tray on the right shows 'Afficher tous les téléchargements...'. The bottom right corner of the slide features the logo and name of the Qatar Computing Research Institute (QCRI) and Hamad Bin Khalifa University.



# Networks

<https://gephi.org/>



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[Home](#) [Features](#) [Learn](#) [Develop](#) [Plugins](#) [Services](#) [Consortium](#)

## The Open Graph Viz Platform

Gephi is an interactive visualization and exploration **platform** for all kinds of networks and complex systems, dynamic and hierarchical graphs.

Runs on Windows, Linux and Mac OS X. Gephi is open-source and free.

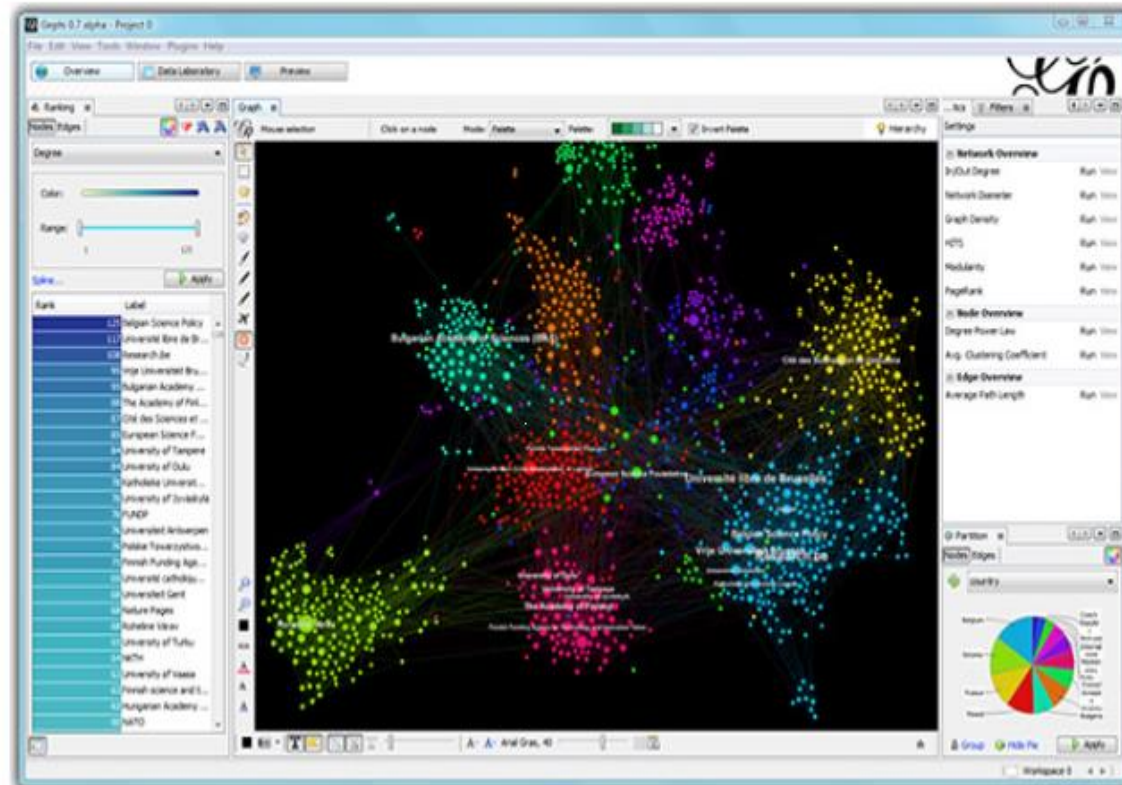
[Learn More on Gephi Platform »](#)



[Release Notes](#) | [System Requirements](#)

- [Features](#)
- [Quick start](#)

- [Screenshots](#)
- [Videos](#)



# Networks

<http://tulip.labri.fr/>

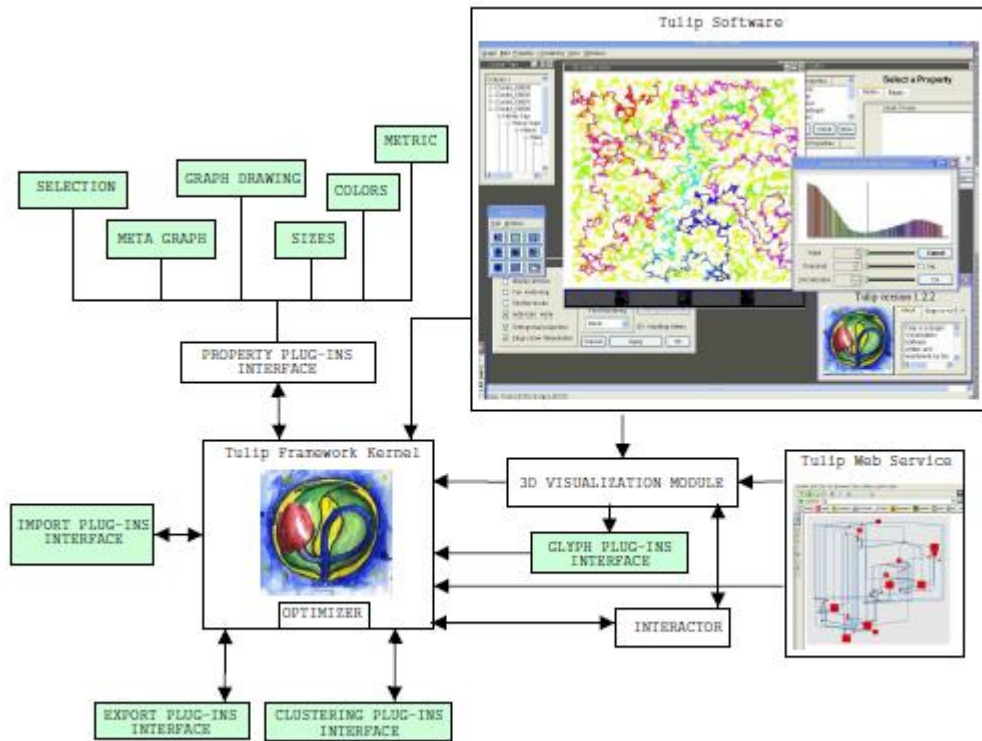
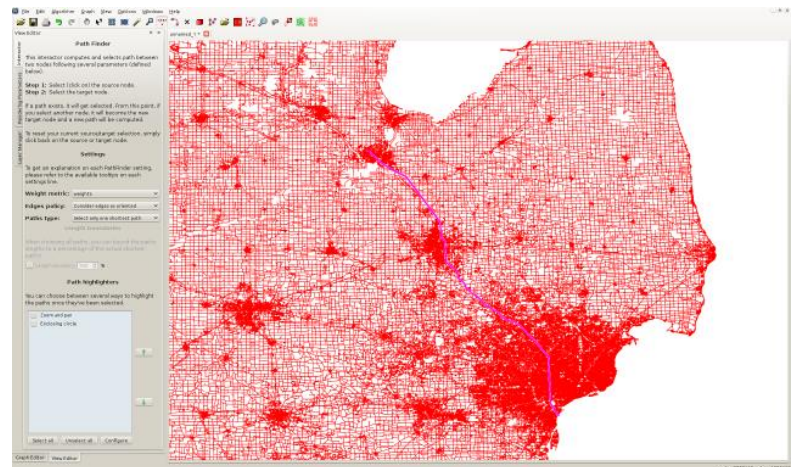
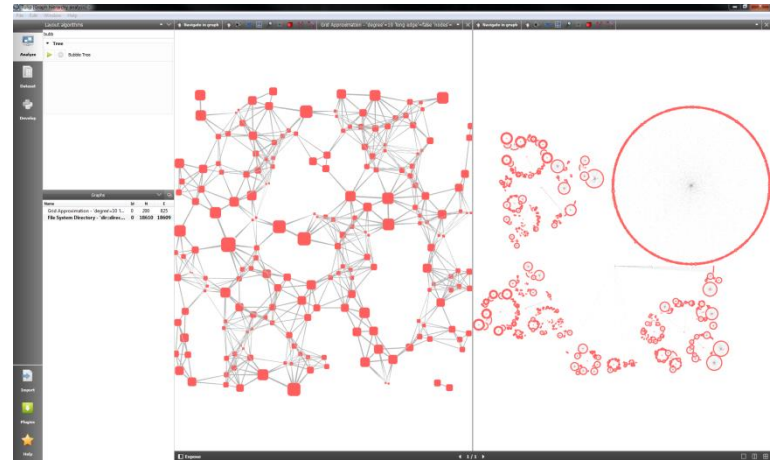


Fig. 16. Tulip Framework overview.







# Visualization coding tools

- <https://www.d3-graph-gallery.com/>
- <https://vegawidget.github.io/vegawidget/>
- <https://blog.jupyter.org/and-voil%C3%A0-f6a2c08a4a93> Jupyter-> Web
- PANEL+BOKEH for Python: <https://medium.com/@philipp.jfr/panel-announcement-2107c2b15f52> <https://www.anaconda.com/intake-discovering-and-exploring-data-in-a-graphical-interface>
- Python visualization: <https://www.anaconda.com/python-data-visualization-2018-why-so-many-libraries/>
- R-Shiny: <https://shinydevseries.com/post/ep0/>
- Plotly: <https://plot.ly/>
- Vis for ML: <http://www.scikit-yb.org/en/latest/index.html>

# Shiny R

- Tutorial:
  - <https://shinydevseries.com/post/ep0/>
  - <https://rstudio.cloud/learn/primers>
- Use Plotly in Shiny: <https://plot.ly/ggplot2/>
- Python from R: <https://rstudio.github.io/reticulate/>
- Parallel coord plot  
<http://timelyportfolio.github.io/parcoords/articles/introduction-to-parcoords-.html>
- Network/Graph R <https://kateto.net/network-visualization>

# Visualization app

- <https://www.tableau.com/>
- <https://charticator.com/app/index.html>
- <https://keshif.me/>

# R toolboxes

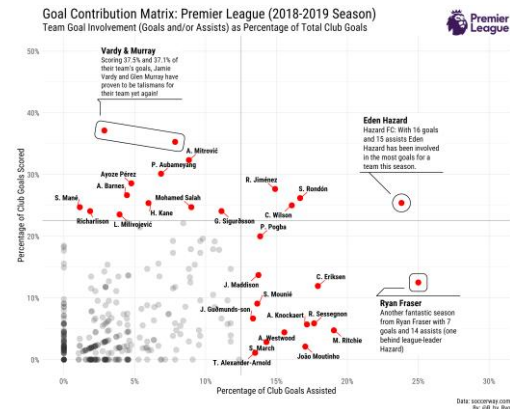
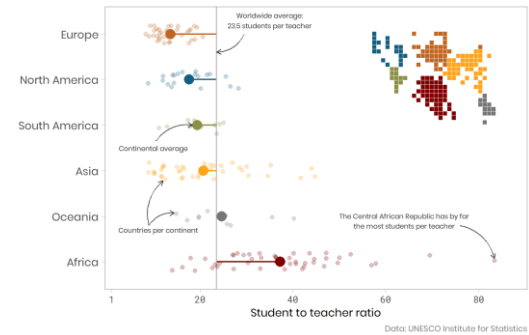
- Compare dataframes:  
[https://github.com/alastairrushworth/inspect\\_df](https://github.com/alastairrushworth/inspect_df)
- Tidyverse:
  - Tidyr: <https://tidyr.tidyverse.org/>
  - Dplyr: <https://dplyr.tidyverse.org/>
  - Purrr: <https://purrr.tidyverse.org/>
  - ggplot2: <https://ggplot2.tidyverse.org/>
  - Readr: <https://readr.tidyverse.org/>

# GGPLOT

- ggforce: <https://www.data-imaginist.com/2019/the-ggforce-awakens-again/>
- gganimate: <https://github.com/thomasp85/gganimate>
- R Cookbook: <https://r-graphics.org/>

## Examples

- <https://cedricscherer.netlify.com/2019/05/17/the-evolution-of-a-ggplot-ep.-1/>
- <https://gist.github.com/Ryo-N7/67ca1c364c342a82c4098918082ca445>



# Online readings

- <https://medium.com/nightingale>
- [http://johnguerra.co/lectures/visualAnalytics\\_12\\_hours/](http://johnguerra.co/lectures/visualAnalytics_12_hours/)
- [https://www.cs.ubc.ca/~tmm/talks.html?utm\\_content=buffer0ca6&utm\\_medium=social&utm\\_source=twitter.com&utm\\_campaign=buffer](https://www.cs.ubc.ca/~tmm/talks.html?utm_content=buffer0ca6&utm_medium=social&utm_source=twitter.com&utm_campaign=buffer)
- <https://sandrarendgen.wordpress.com/2019/05/28/history-raise-the-bar-1770s/>

# Visual Perception

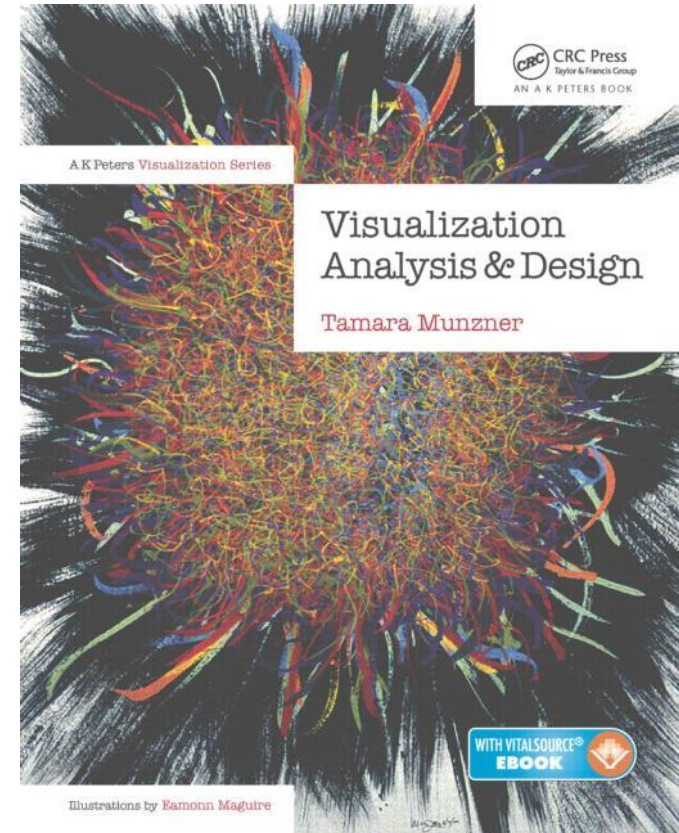
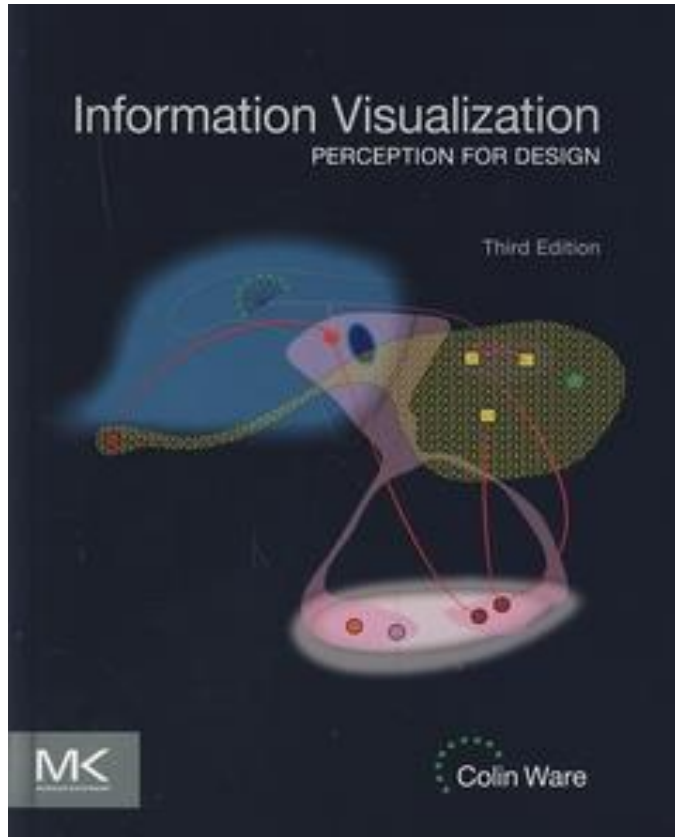
- <https://medium.com/@kennelliott/39-studies-about-human-perception-in-30-minutes-4728f9e31a73>



# Story telling viz

- <https://pudding.cool/2019/04/eu-regions/>
- <https://twitter.com/alexcengler/status/1101245224733605891>
- <http://brussels-diversity.jetpack.ai/>
- <https://tonofshell.me/us-broadband-interactive/>
- Give this link <http://www.visualisingdata.com/2019/06/best-of-the-visualisation-web-april-2019/>
- <https://timelinestoryteller.com/>  
<https://timelinestoryteller.com/app/>
- GAPMINDER : [https://www.gapminder.org/tools/#\\$chart-type=bubbles](https://www.gapminder.org/tools/#$chart-type=bubbles) + **show data doubt WARNING**

# Books



# Thank you !