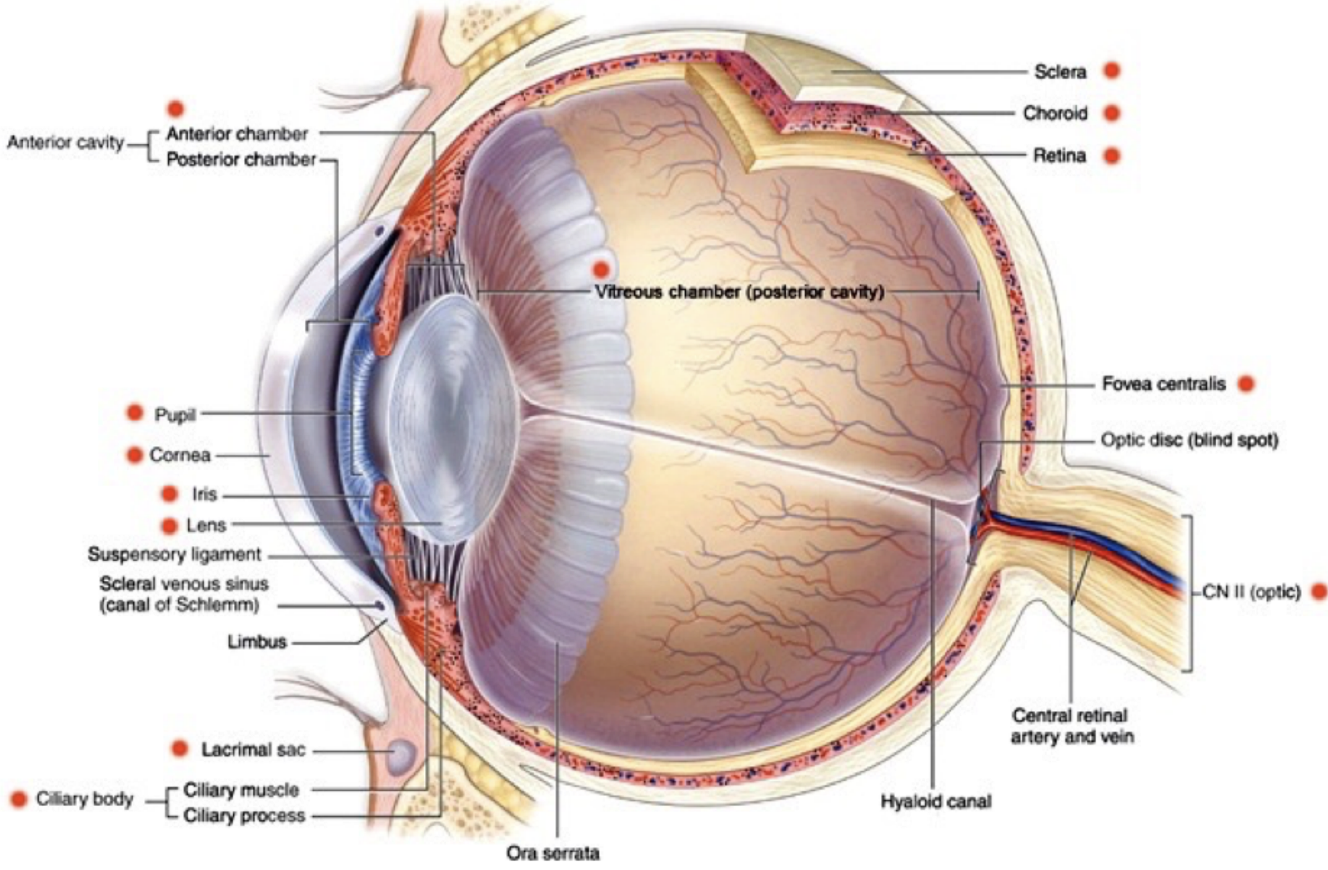


psychophysics

The study of human perception

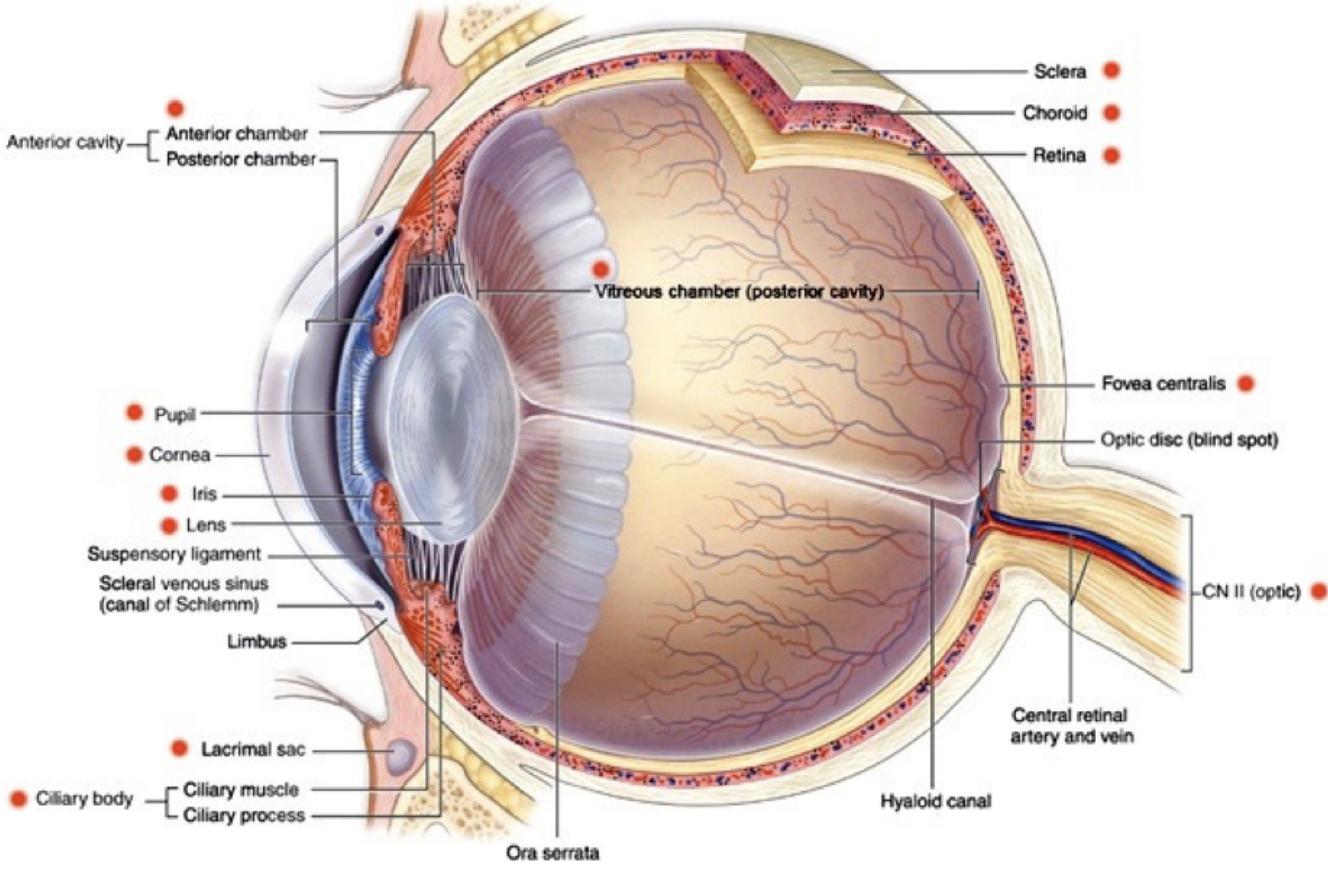
why do we visualize? cause our brain is best suited to receive visual sitmuly (compared to tactile or auditorial for example)

alternatives:

sonification
https://en.wikipedia.org/wiki/Sonification

tactile maps

https://www.nasa.gov/audience/foreducators/a-feel-for-astronomy.html



psychophysics

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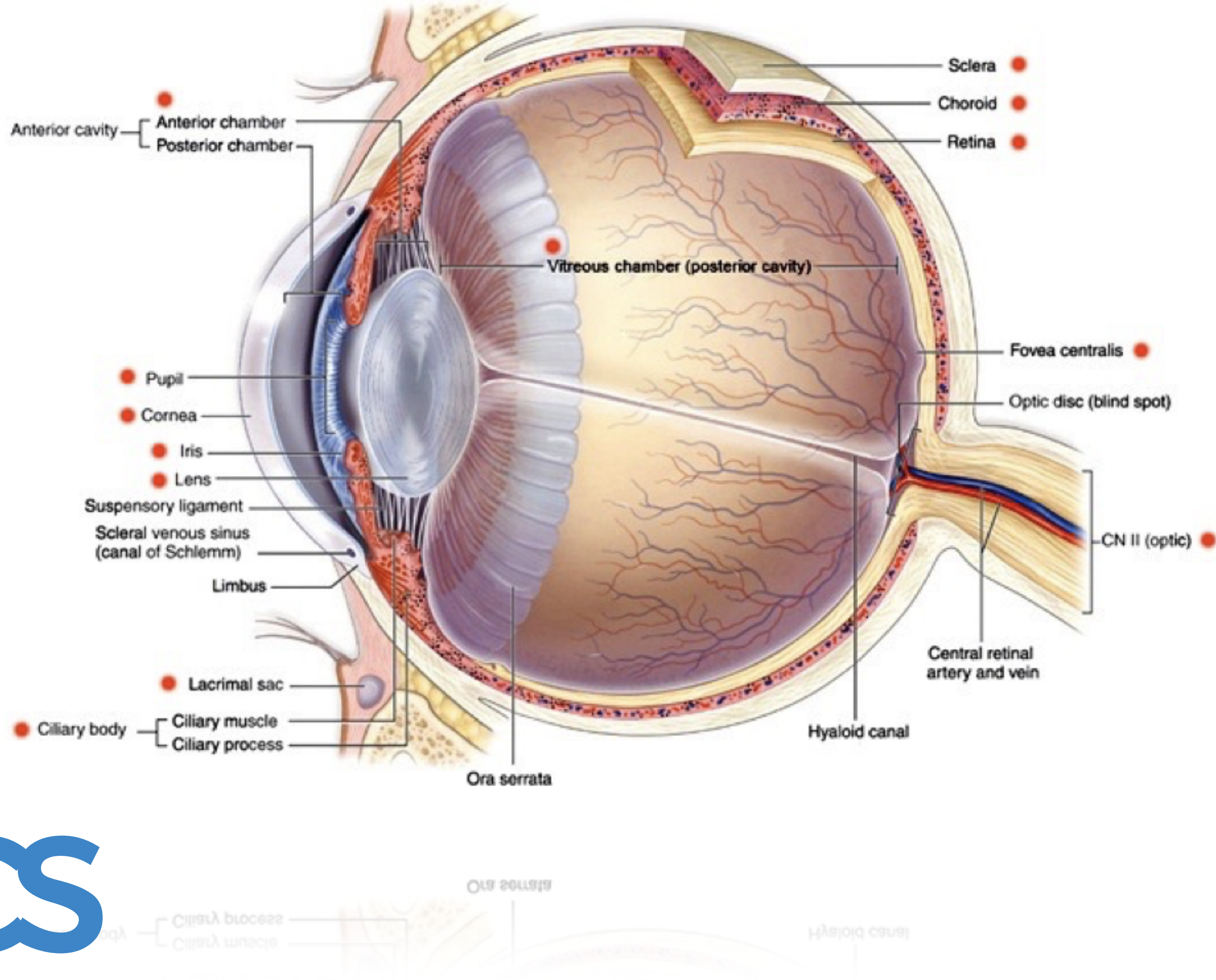
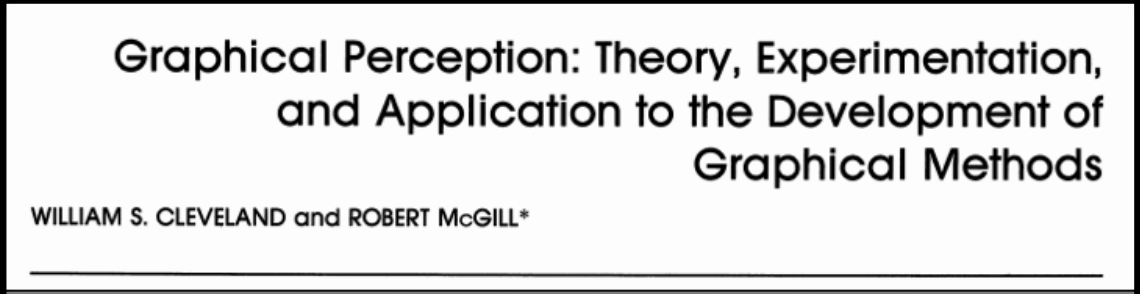


psychophysics

exploring these alternative is important as a social justice issue to make science and data science accessible to vision impaired people but also: can the different ways in which we process information can give new insight?

e.g.: we process visual stimuli but sound stimuli holistically (we hear a chord, not the notes in it)


Graphical Perception: Theory, Experimentation, and Application to the Development of Graphical Methods

WILLIAM S. CLEVELAND and ROBERT McGILL*

psychophysics

The study of human perception
here limited to visual stimuli

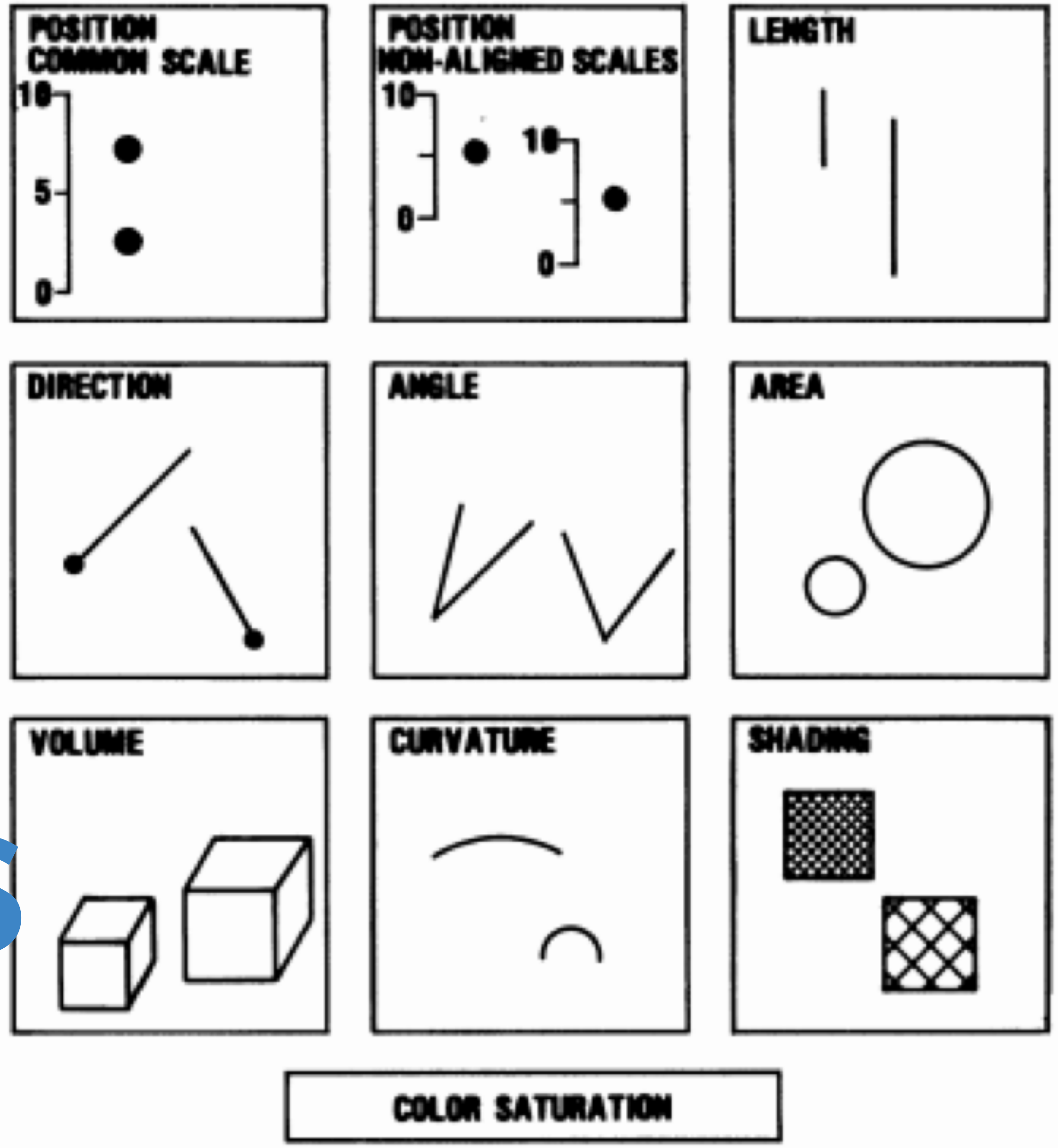


Figure 1. Elementary perceptual tasks.

Stevens 1975

Psychophysical power law

The apparent magnitude of all sensory channels follows a power law based on the stimulus intensity

$$S = I^n$$

S sensation, I intensity

Stevens 1975

response to length: $I = S$

when shown something 4x as long we perceive it as being 4x as long

response to brightness: $I = \sqrt{S}$

when shown something 4x as bright we perceive it as being 2x as bright

response to saturation: $I = S^{1.7}$

when shown something 4x as saturated we perceive it as being 11x as saturated

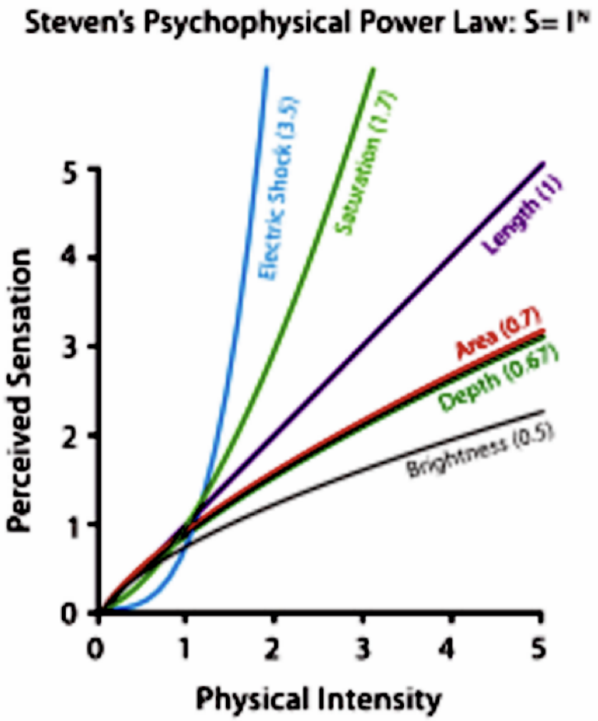


Figure 5.7. Stevens showed that the apparent magnitude of all sensory channels follows a power law $S = I^n$, where some sensations are perceptually magnified compared with their objective intensity (when $n > 1$) and some compressed (when $n < 1$). Length perception is completely accurate, whereas area is compressed and saturation is magnified. Data from Stevens [Stevens 75, p. 15].

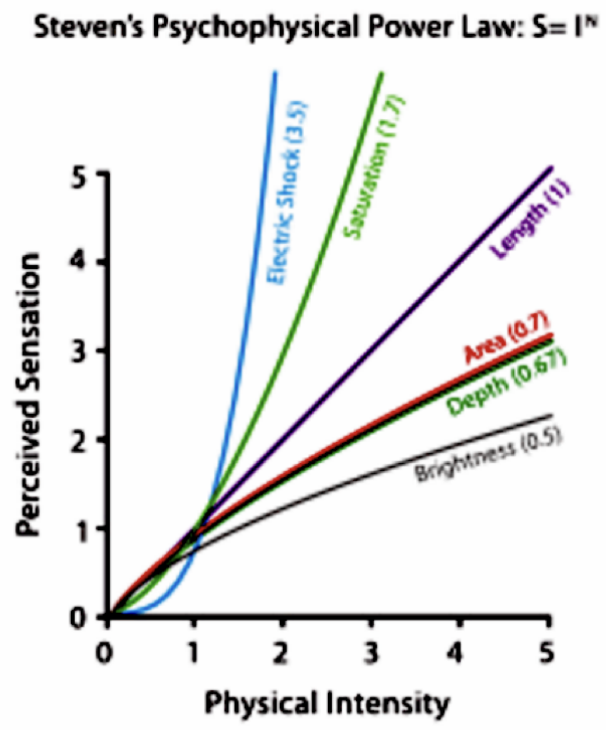
Stevens 1975

response to electroshock: $I = S^{3.5}$

when given an electroshock 4x as strong

we perceive it as 128x as strong

(personally, I do not know of any electroshock based visualizations)



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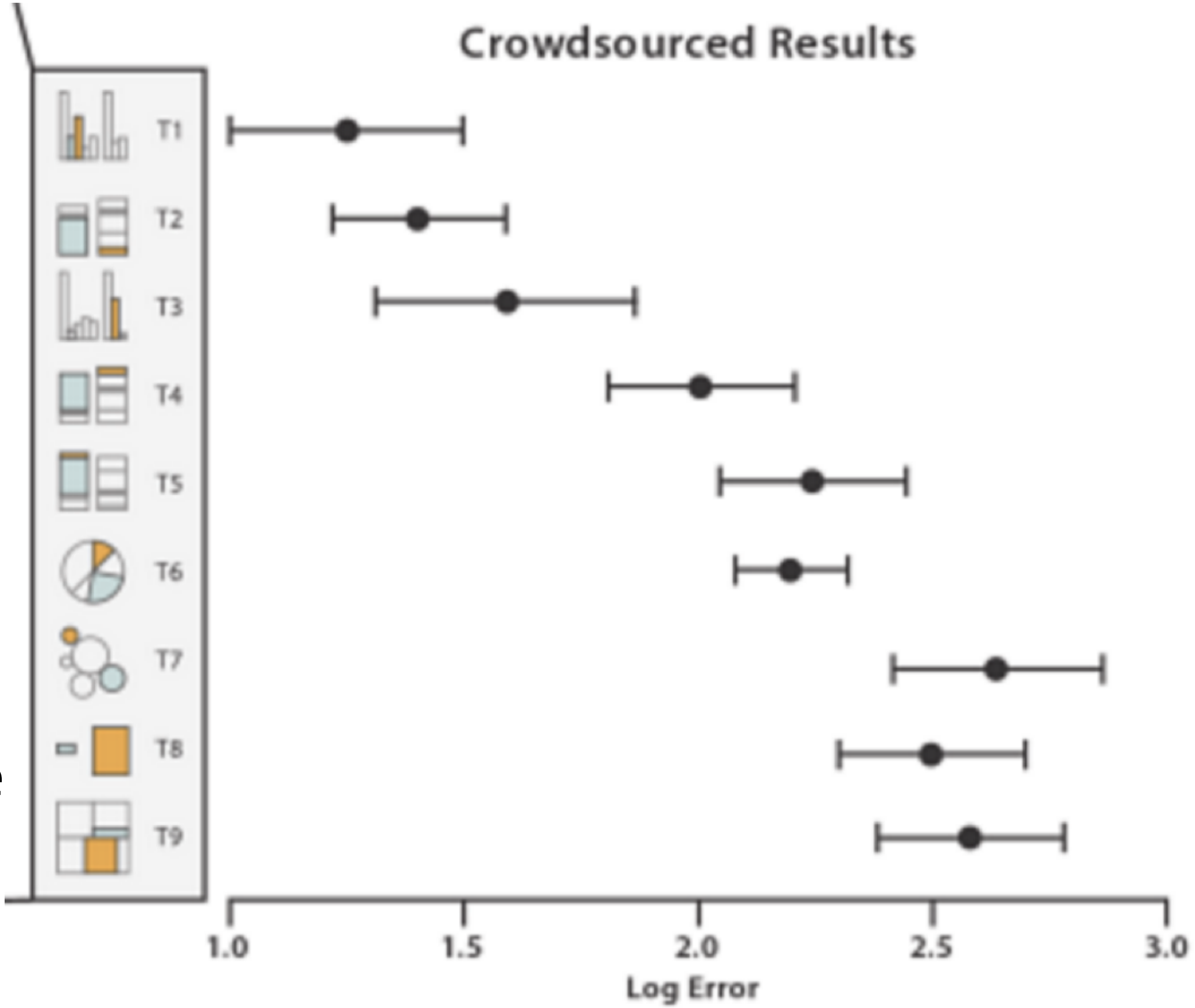
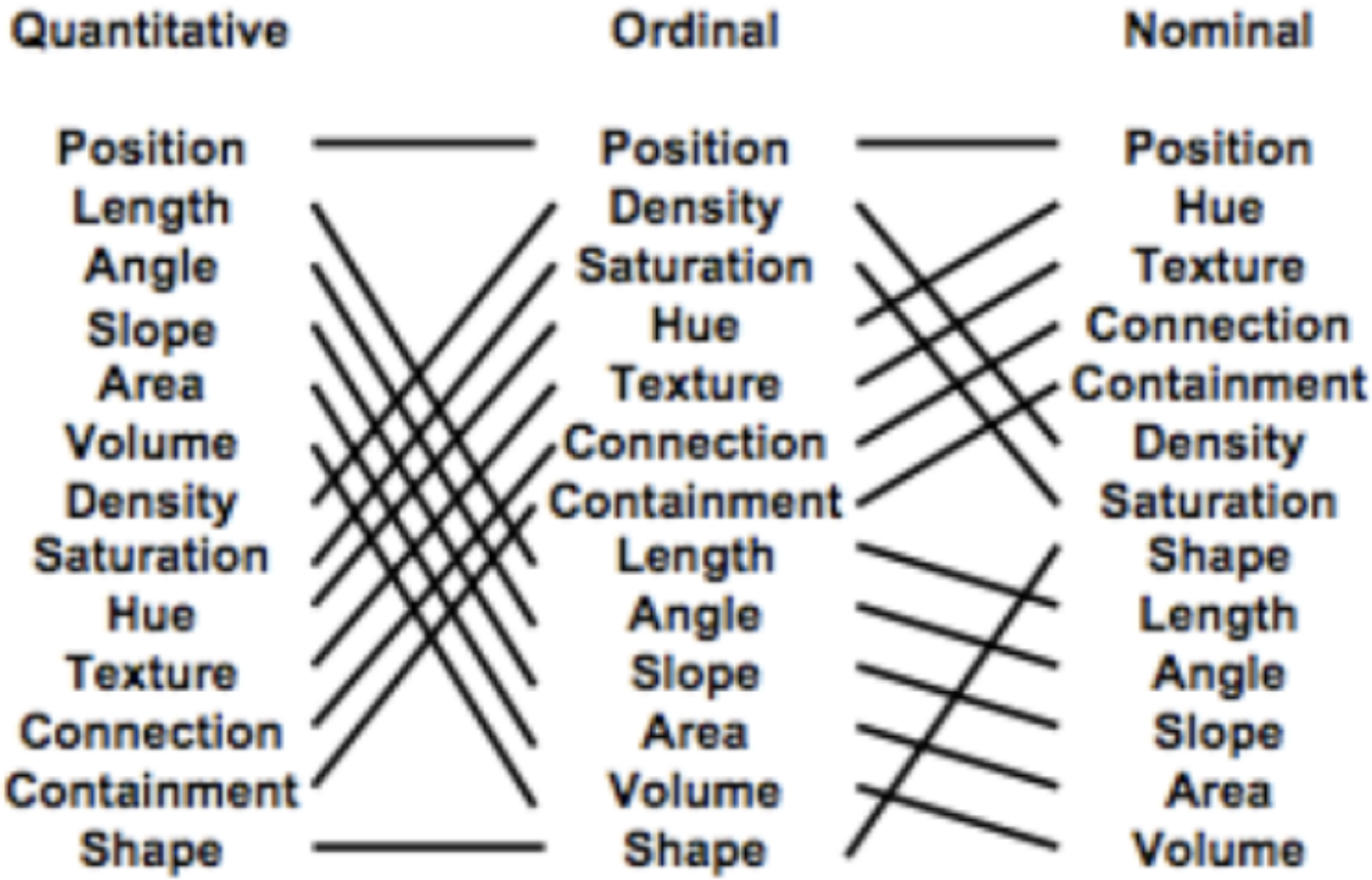
Heer and Bostock 2010

modern version gets uncertainties to these quantities by crowdsourcing the tests





[Mackinlay, Automating the Design of Graphical Presentations of Relational Information, ACM TOG 5:2, 1986]

Weber law

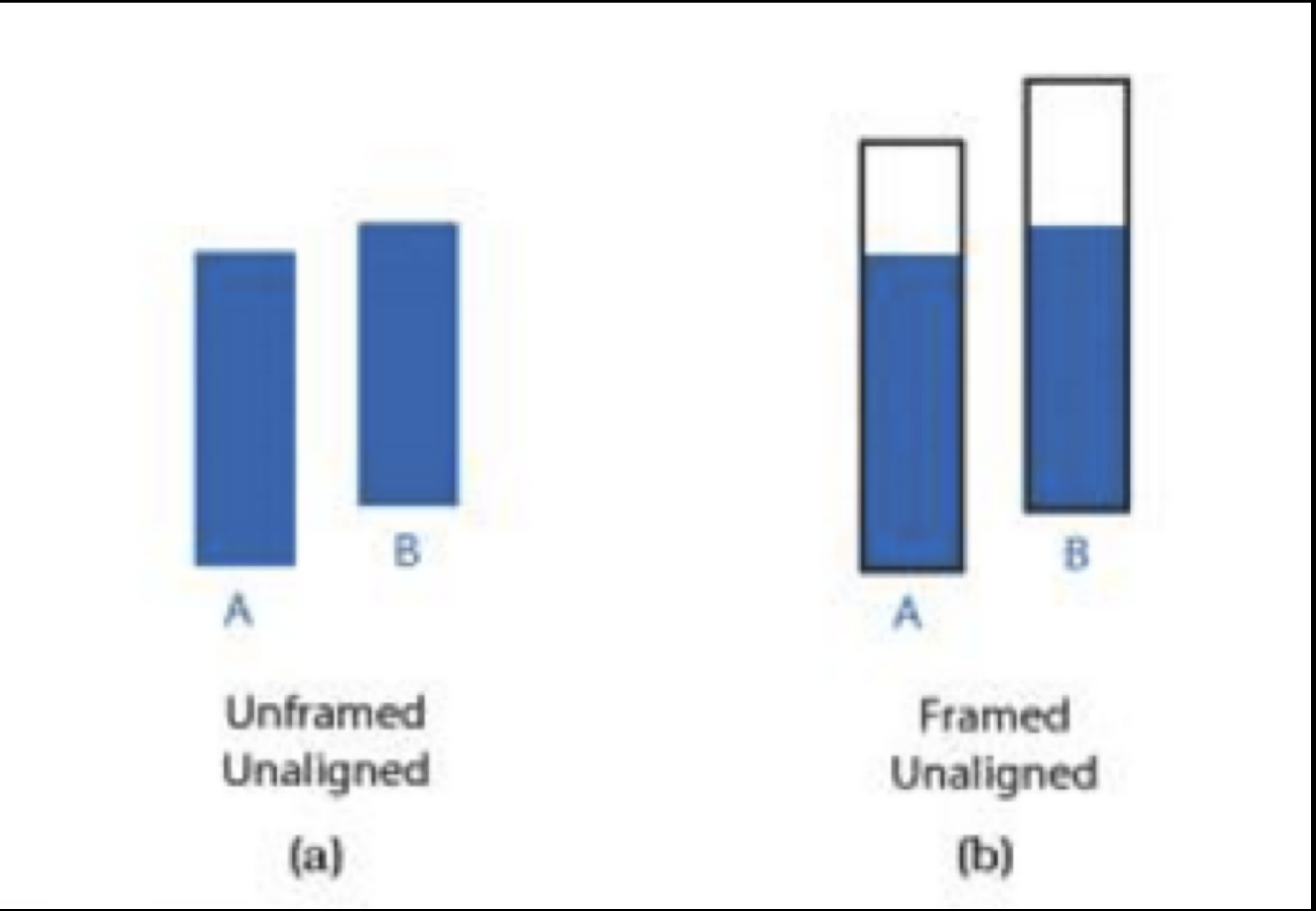
We judge based on relative differences

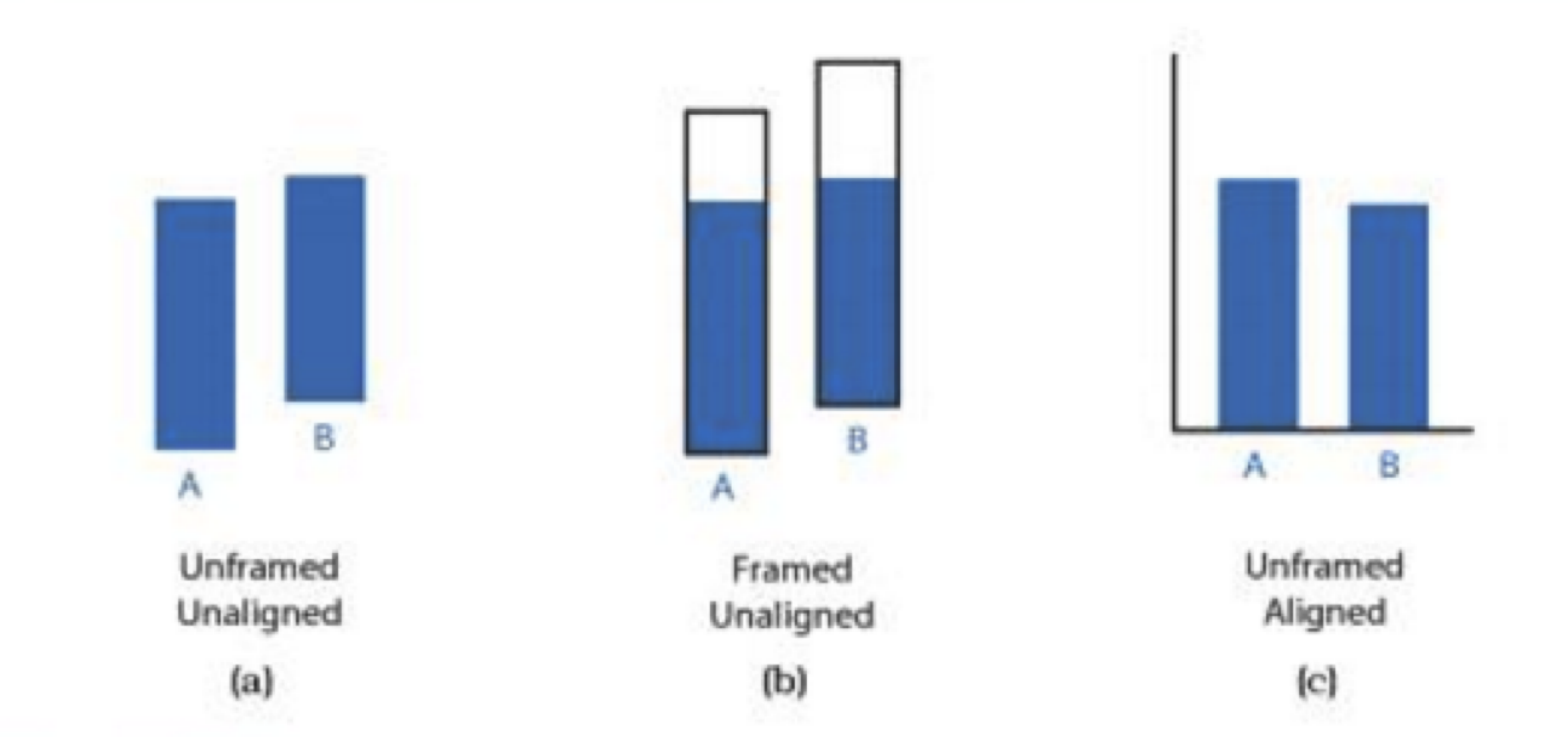
The detectable difference in stimulus intensity is a fixed percentage of the object magnitude

$$\delta I / I = K$$

I intensity, K constant

(a)


A
B
Unframed
Unaligned
(a)
A
B
Framed
Unaligned
(b)


A
B
Unframed
Unaligned
(a)
A
B
Framed
Unaligned
(b)
A
B
Unframed
Aligned
(c)

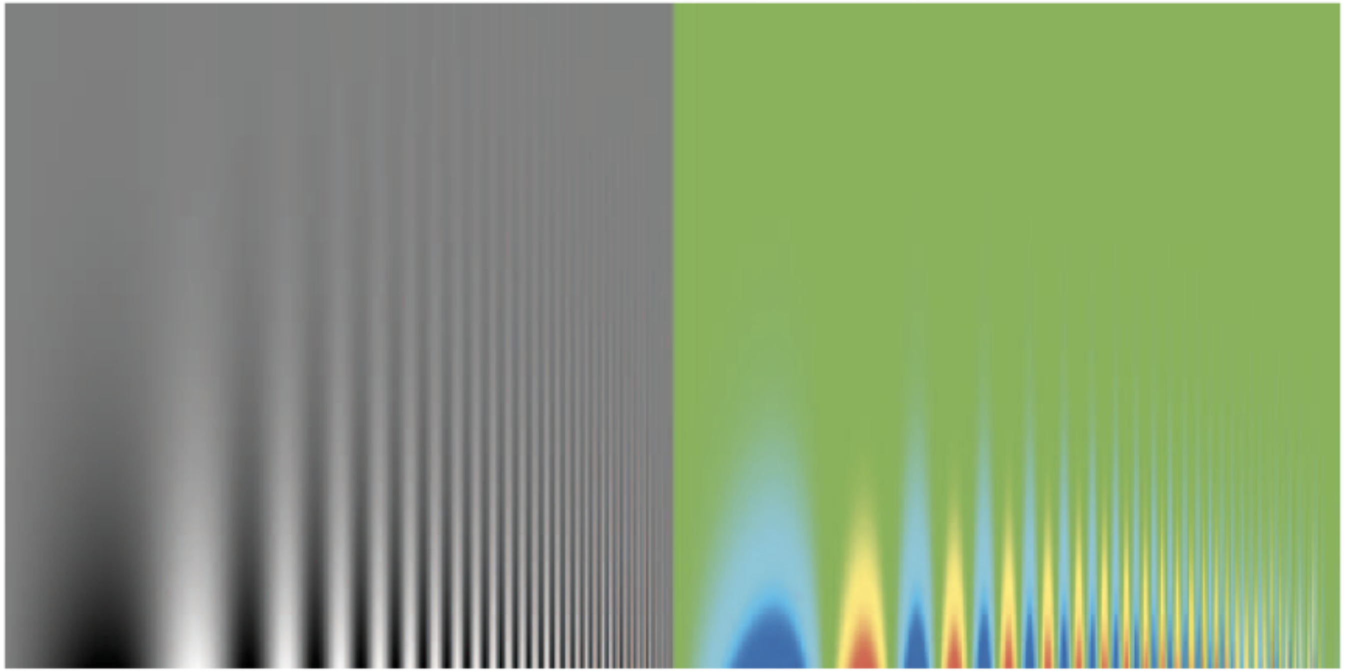
Color

theory

(and good practice)

Good and Bad color choices

5. **Detail is actually harder to see in a rainbow.**
   The logic that it is easier to see detail in a range when you add colors seems to make sense, but in reality, more detail can be seen in a single hue image with a high brightness range.



(source)

http://blog.visual.ly/rainbow-color-scales/

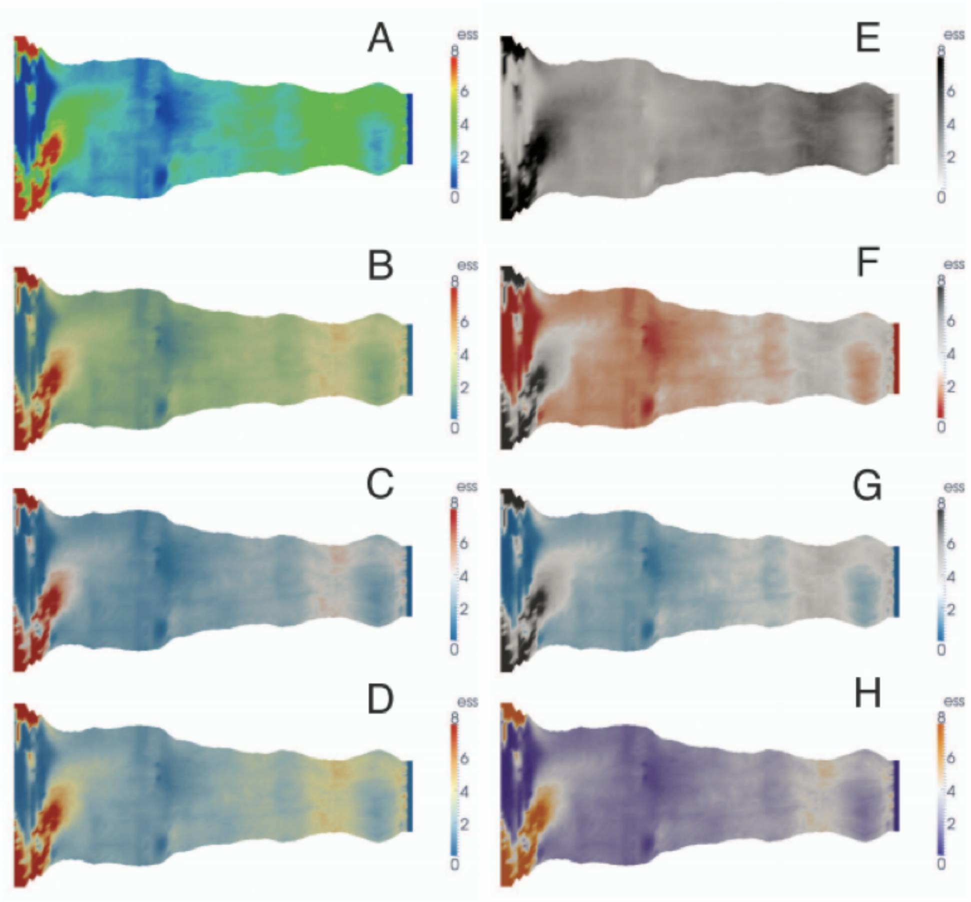
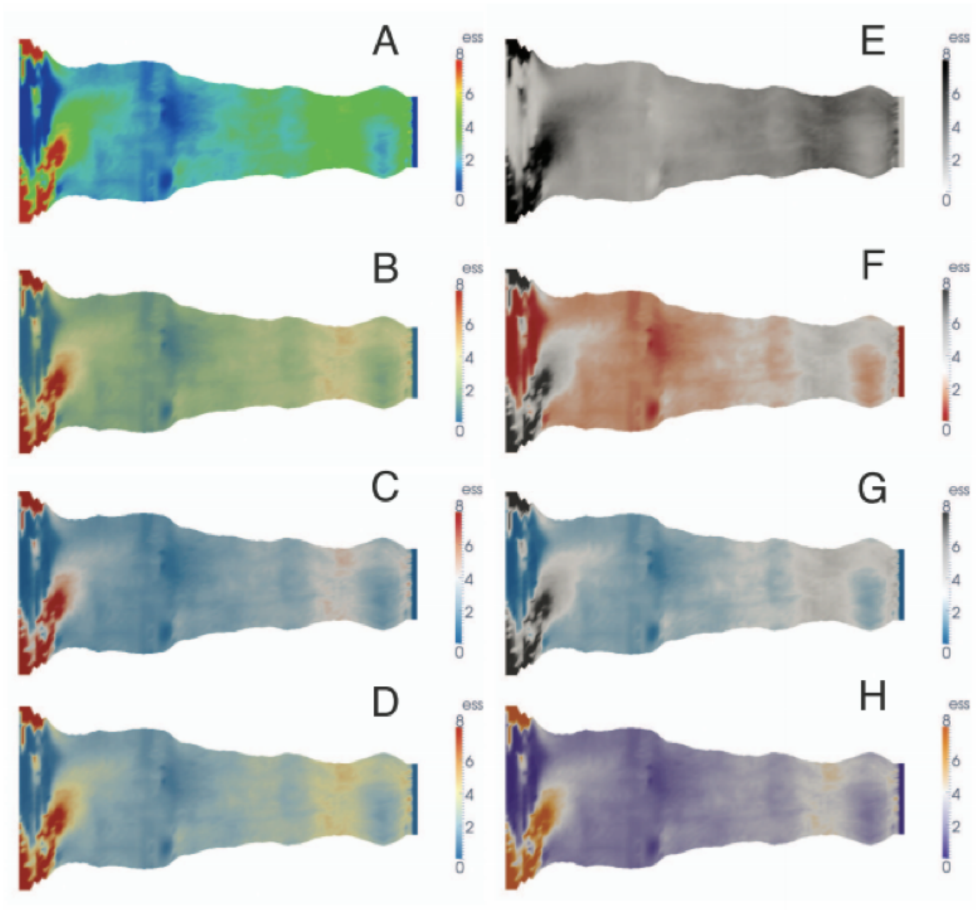


Fig. 4. Color schemes presented during the qualitative user study. The rainbow scheme (A) was preferred by most since it is what they are accustomed to viewing. The next most popular scheme was the red-black diverging scale (F). The grayscale image (E) was unanimously disliked since participants assume black-and-white images to be raw radiological data, while color indicates that the data has been processed or simulated.

very real consequences of bad color choices

Borkin et al. 2011

http://www.eecs.harvard.edu/~kgajos/papers/2011/borkin11-infoviz.pdf



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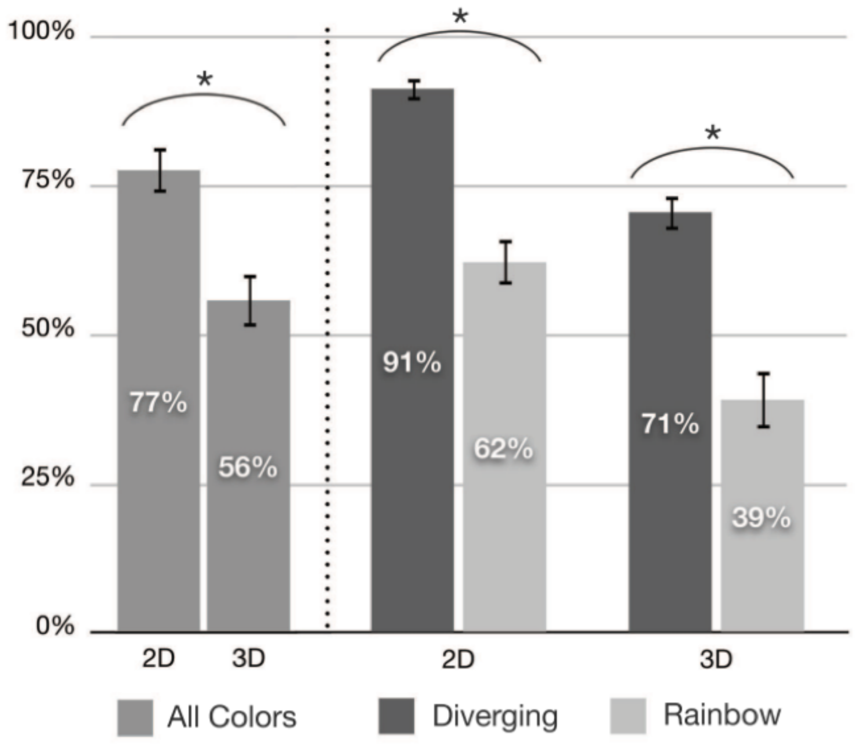
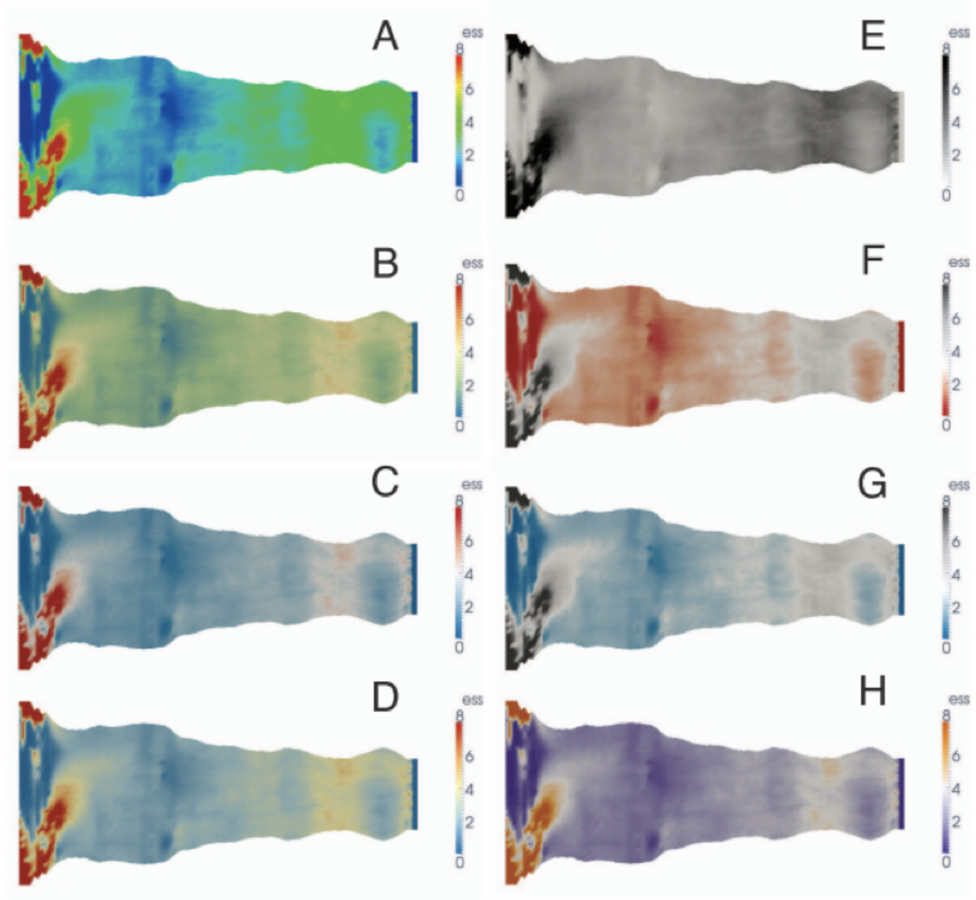


Fig. 7. **Average percent of low ESS regions identified** broken down by 2D and 3D representation, and color. Error bars correspond to the standard error and the asterisks indicate results of statistical significance. Participants were more accurate in 2D and when using the diverging color map.

Borkin et al. 2011

http://www.eecs.harvard.edu/~kgajos/papers/2011/borkin11-infoviz.pdf



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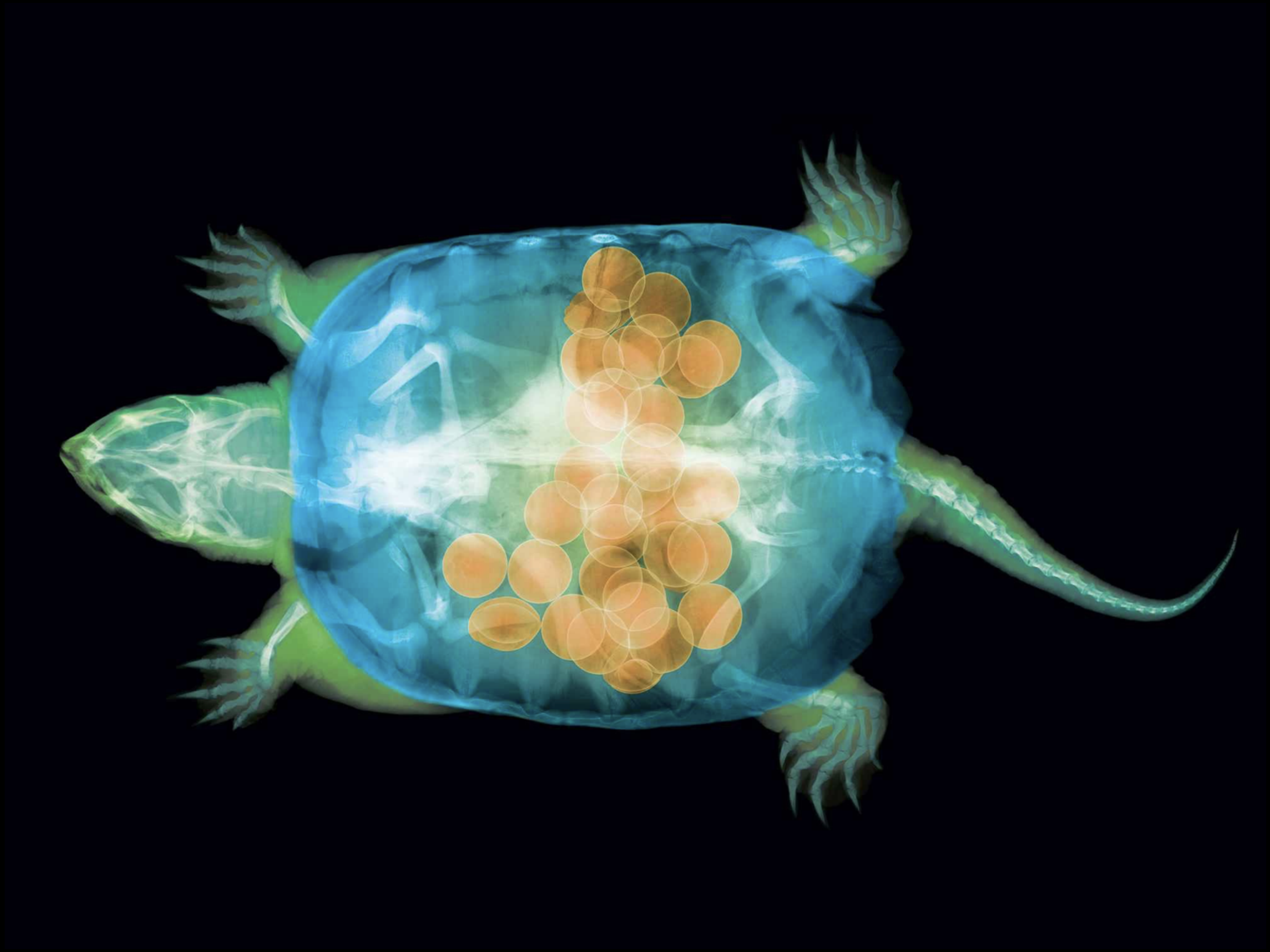
1) Never use Rainbow

2) Use *diverging* color maps for data there the center value is "special" (e.g. 0, with data ranging from positive to negative. In a diverging cm the center of the range is white or black

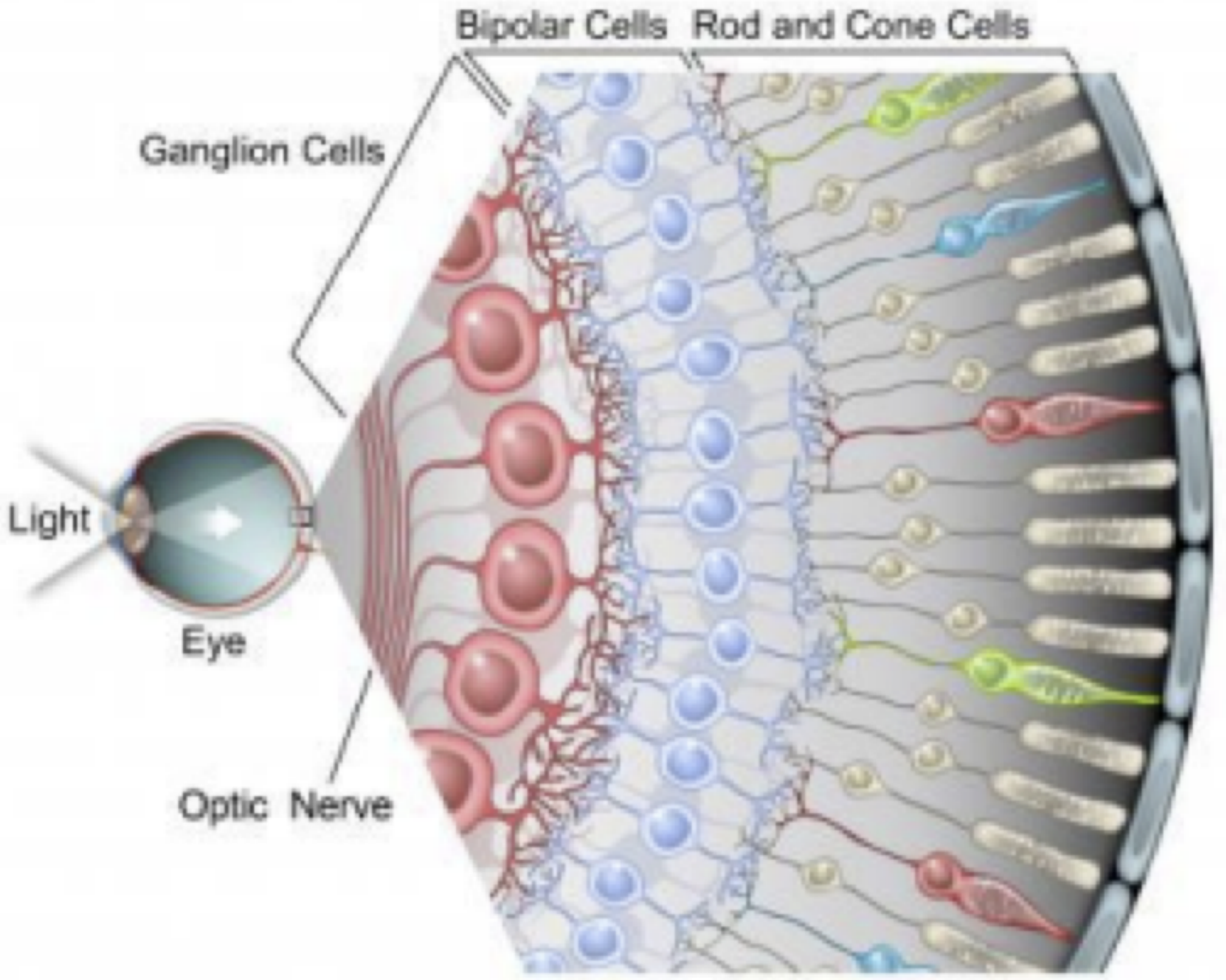
3) Choose a *perceptually uniform* color map for continuous data that does not have a focal point (a special point inside the range)

4) Choose a sequantial cm if your data range represents a progression (reflects some intentity property of the data

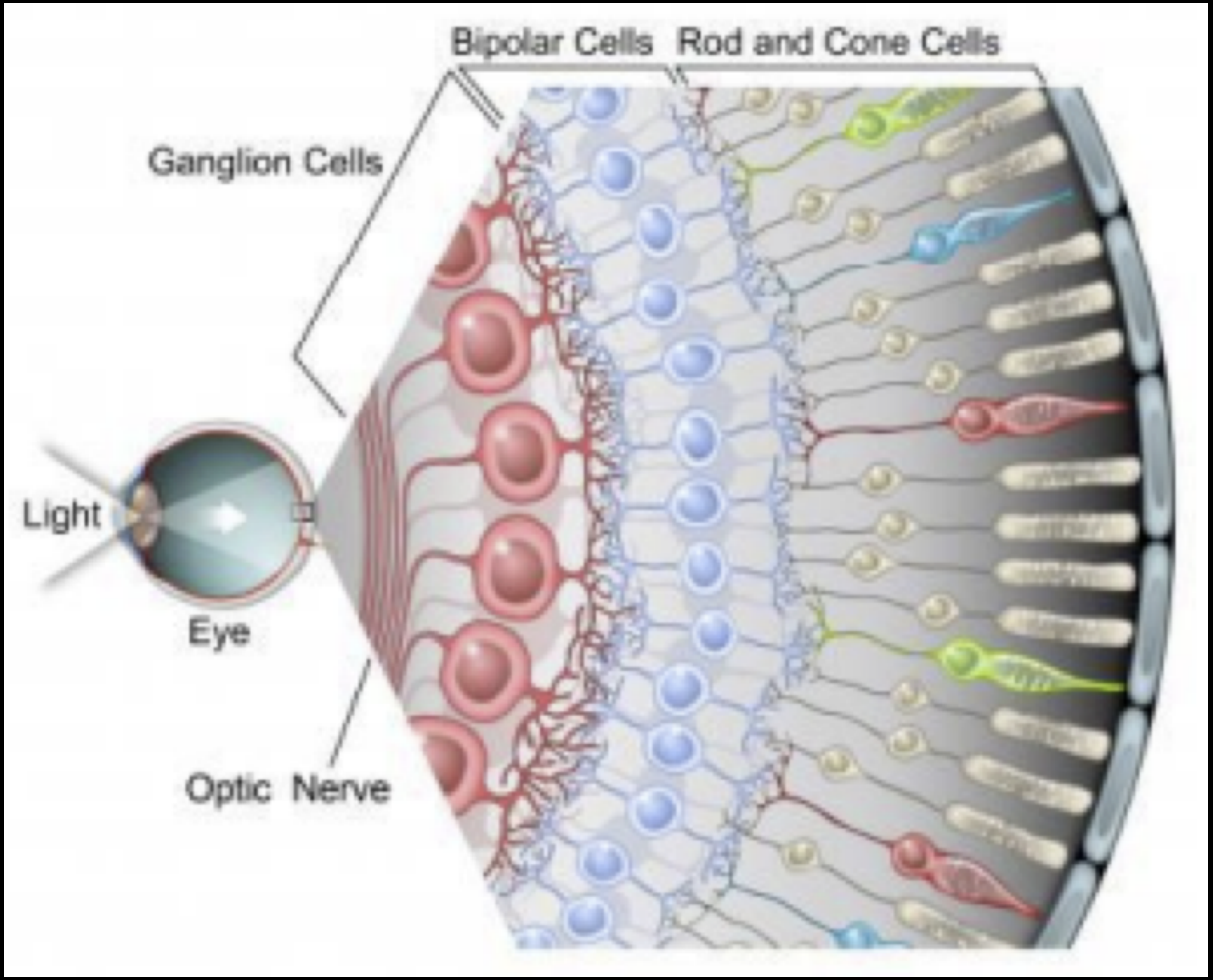


http://www.popsci.com/2015-vizzies-science-visualizations-video-images?image=0

Eye Physiology and color perception deficiencies

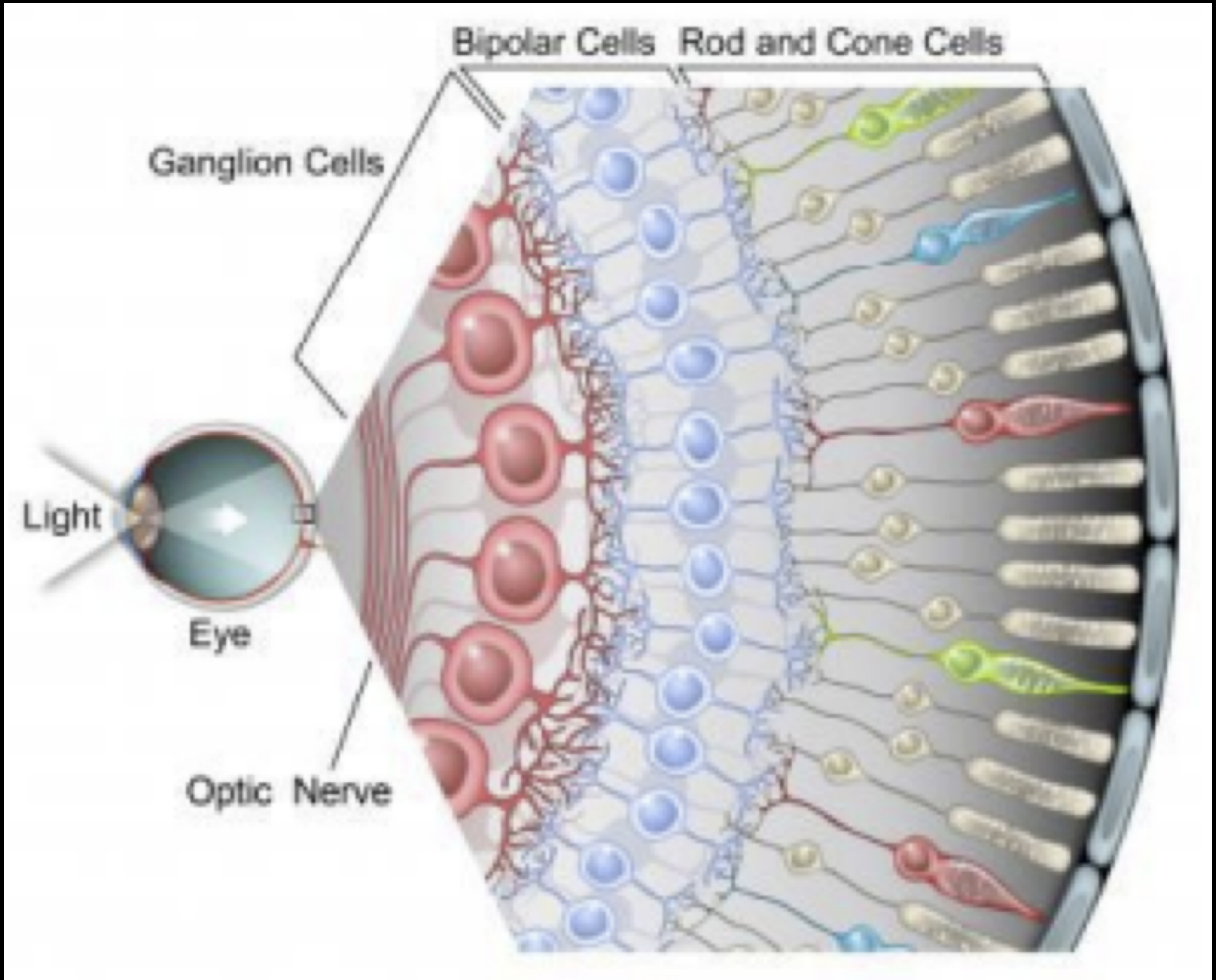


Rods | Cones


Bipolar Cells
Rod and Cone Cells
Ganglion Cells
Light
Eye
Optic Nerve

Rods | Cones

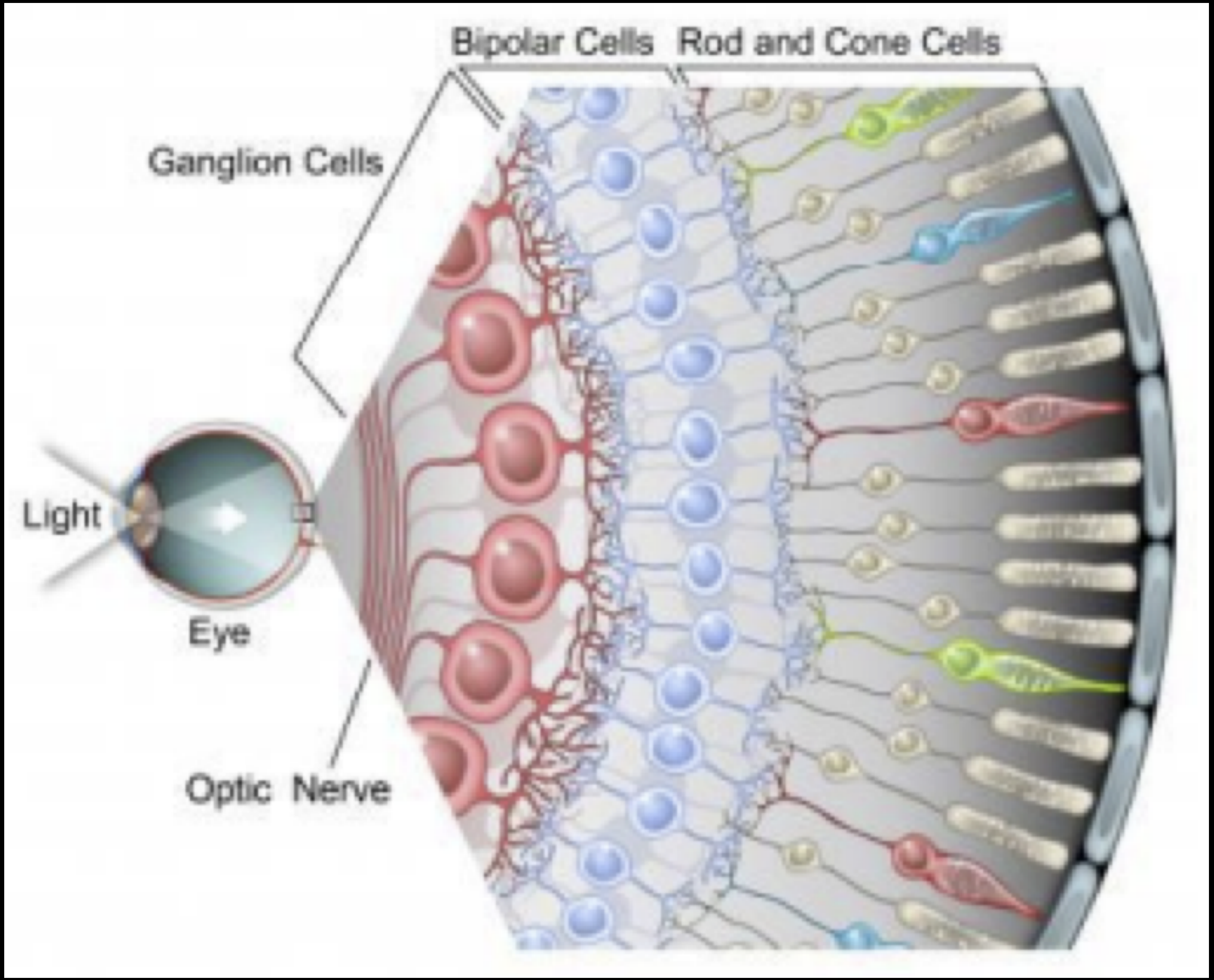
Brightness | Color



Rods | Cones

Brightness | Color

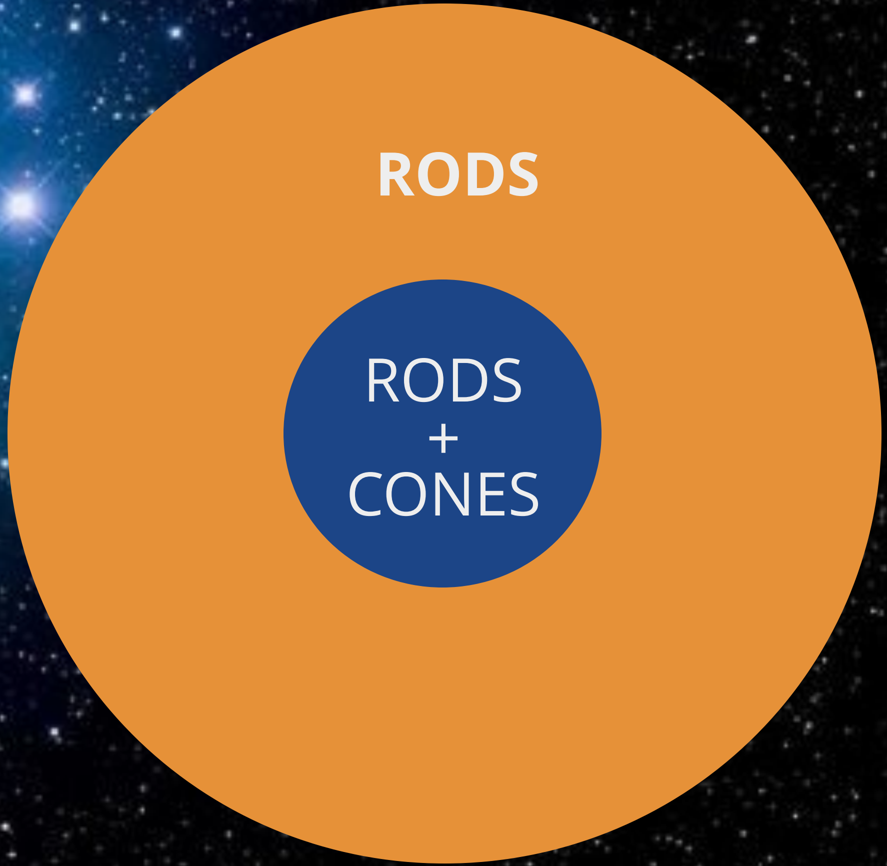
80M | 5M



Rods | Cones

Brightness | Color

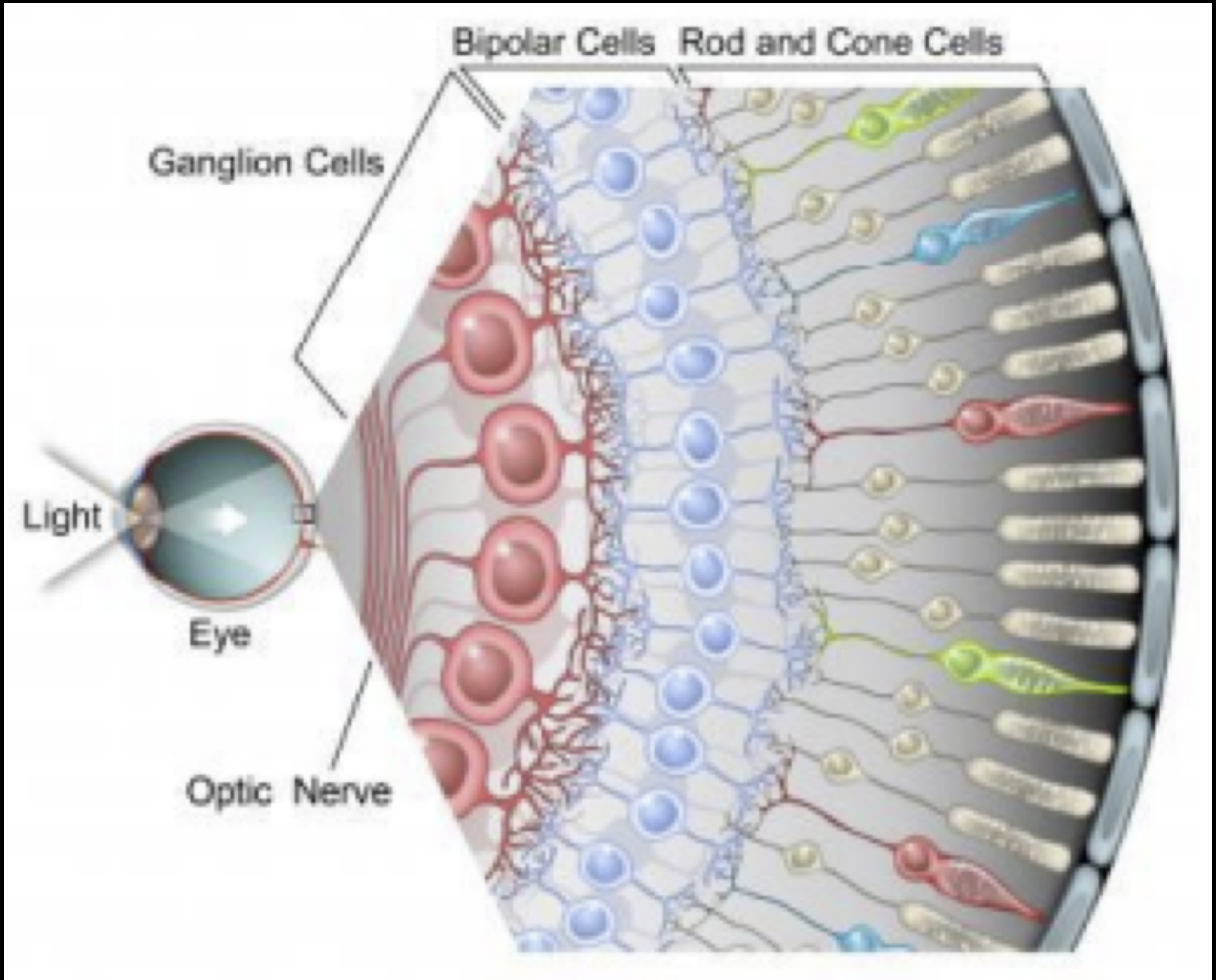
80M | 5M



Rods | Cones

Brightness | Color

R G B



color blindness

Color blindness (color vision deficiency, CVD) affects approximately

1 in 12 men (8%) and 1 in 200 women

in the world.

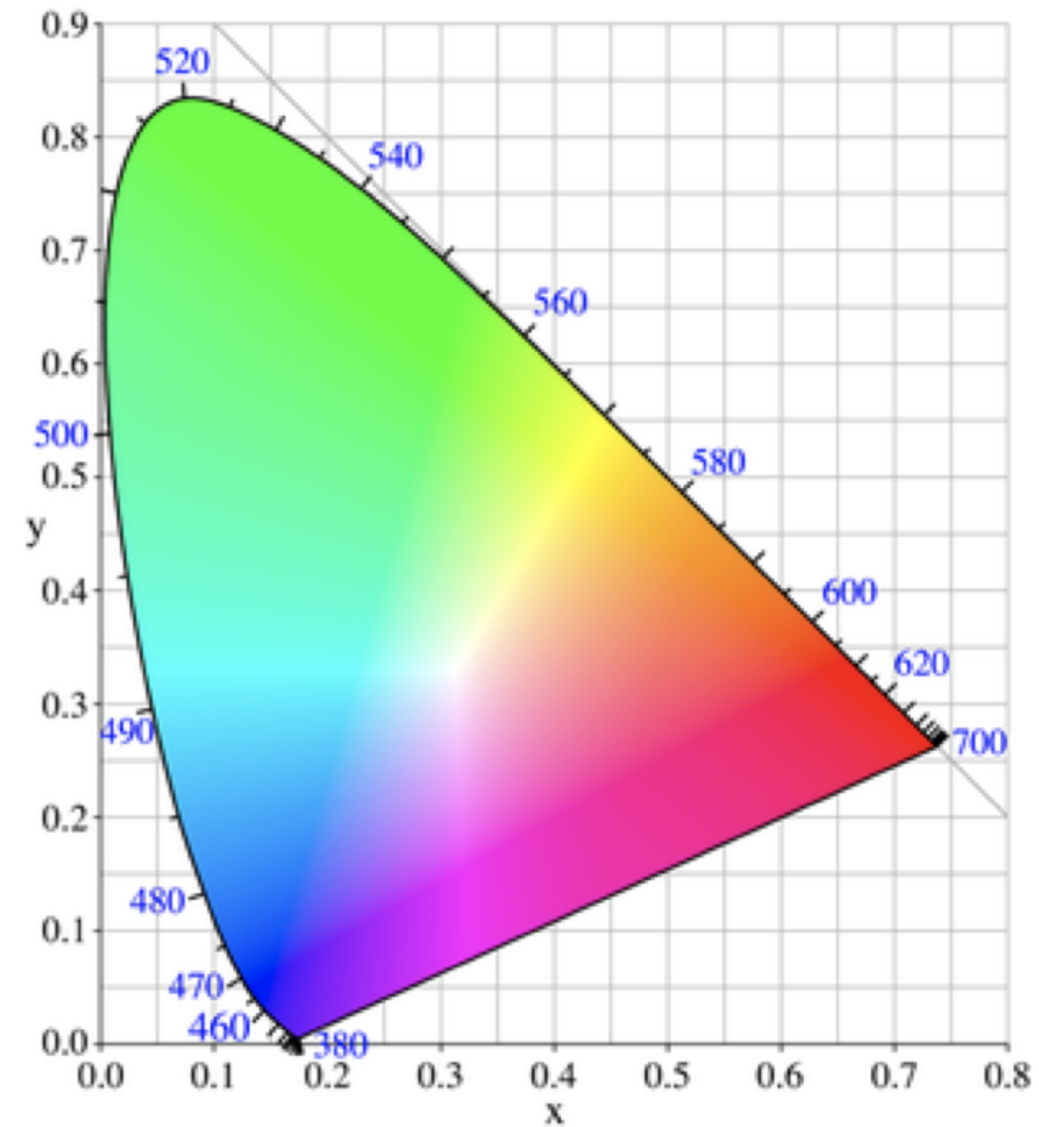
Worldwide, there are approximately 300 million people with colour blindness, almost the same number of people as the entire population of the USA!

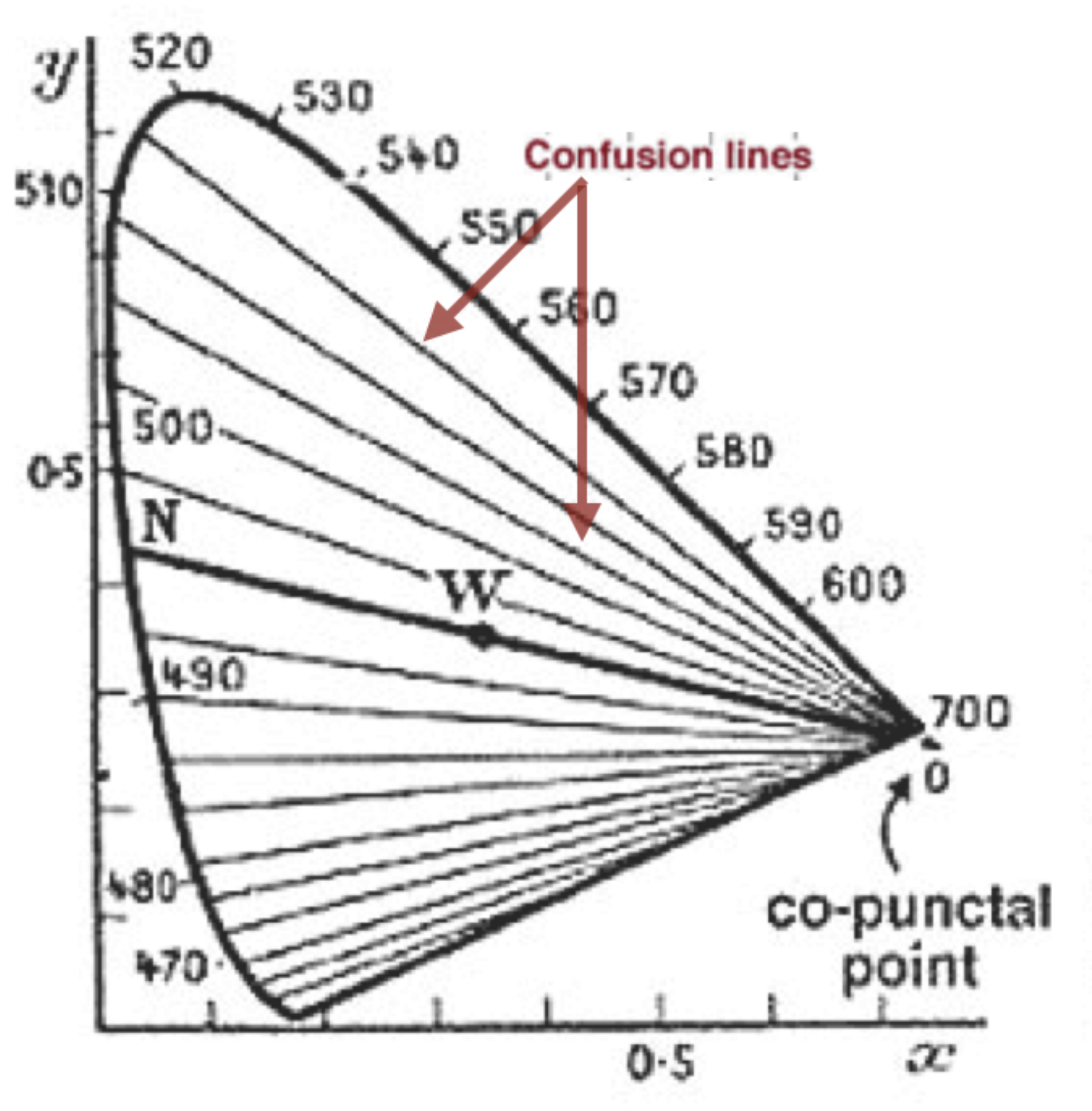
http://www.colourblindawareness.org/colour-blindness/

color blindness

http://www.colourblindawareness.org/colour-blindness/

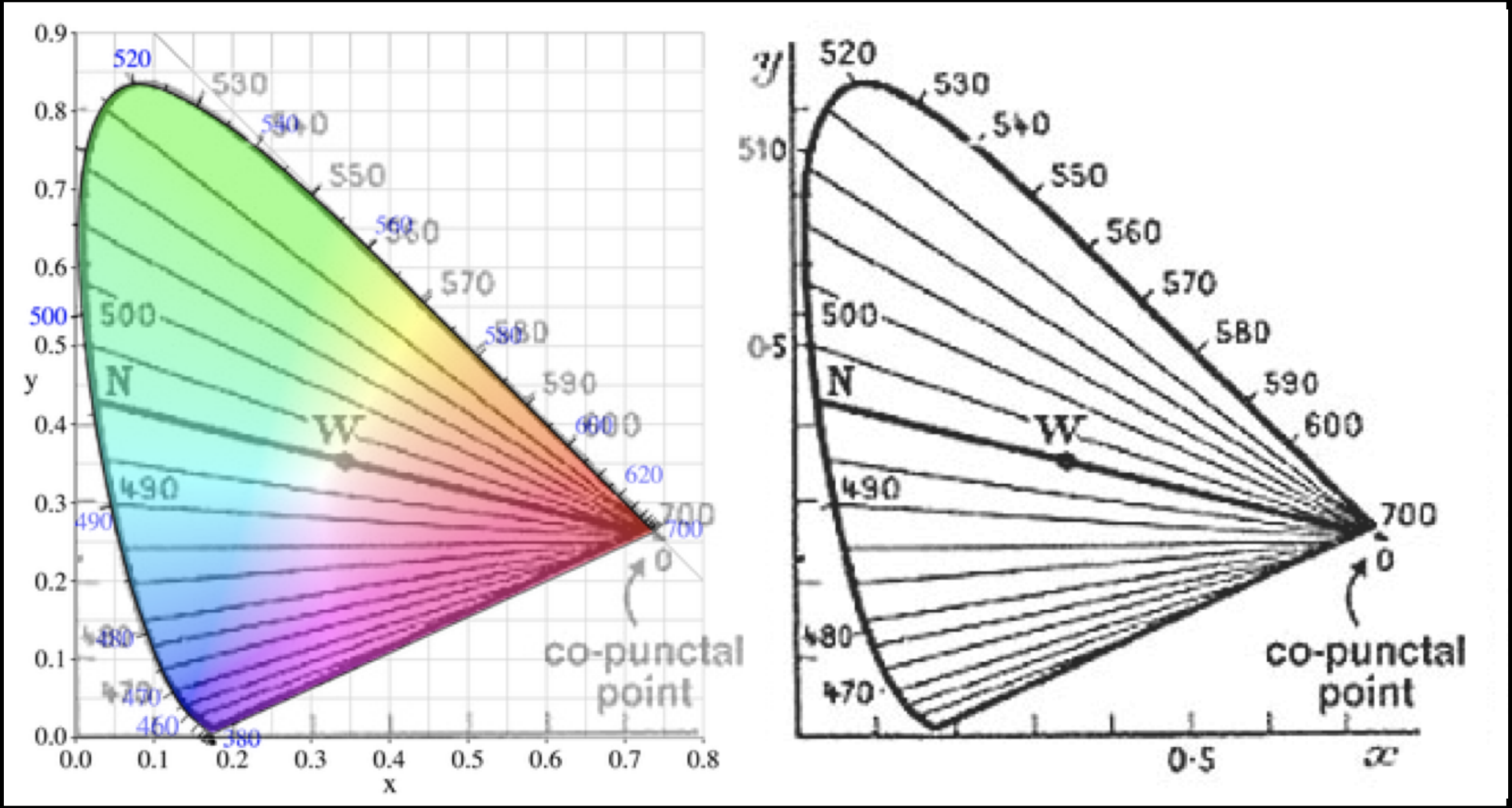
color blindness





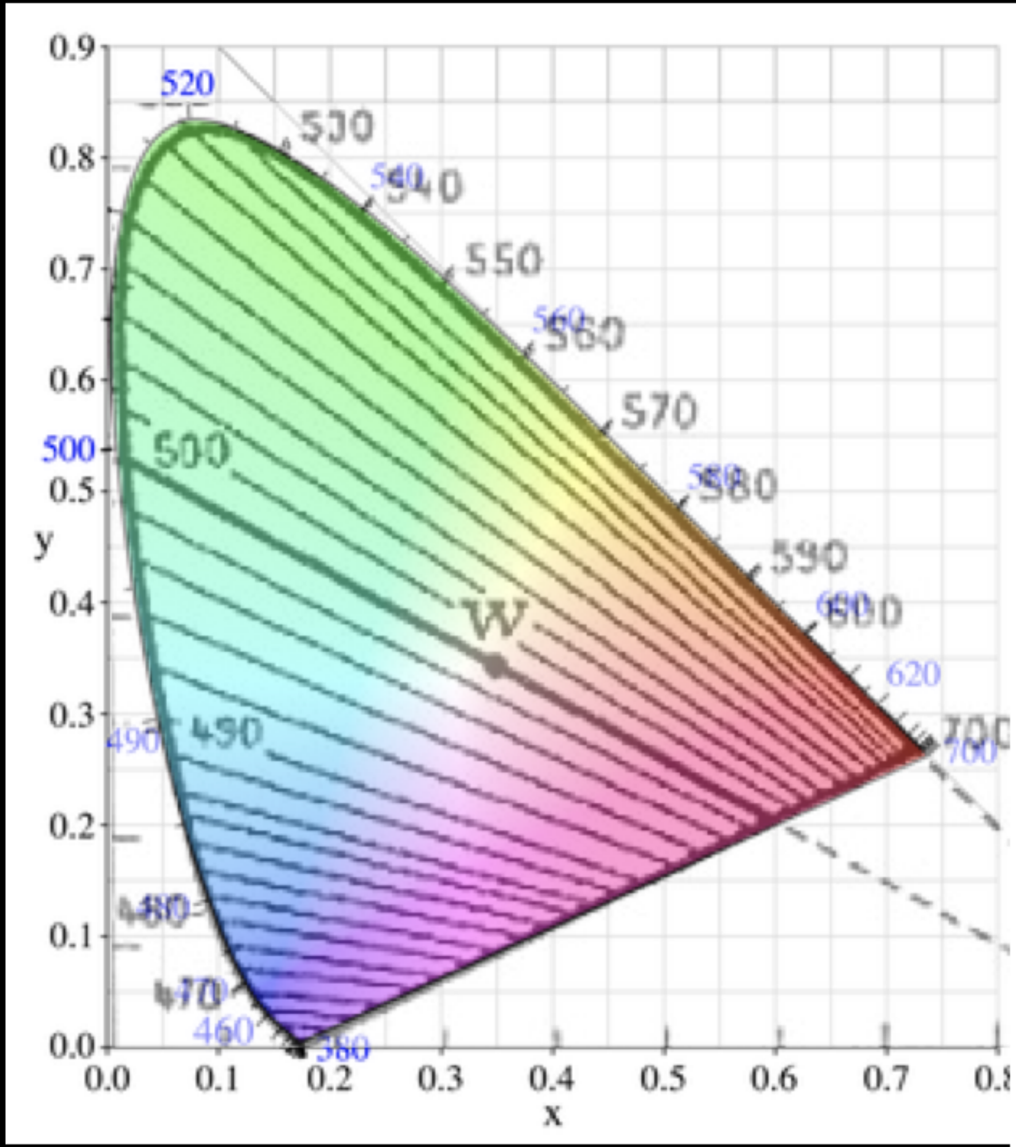
Protanopia

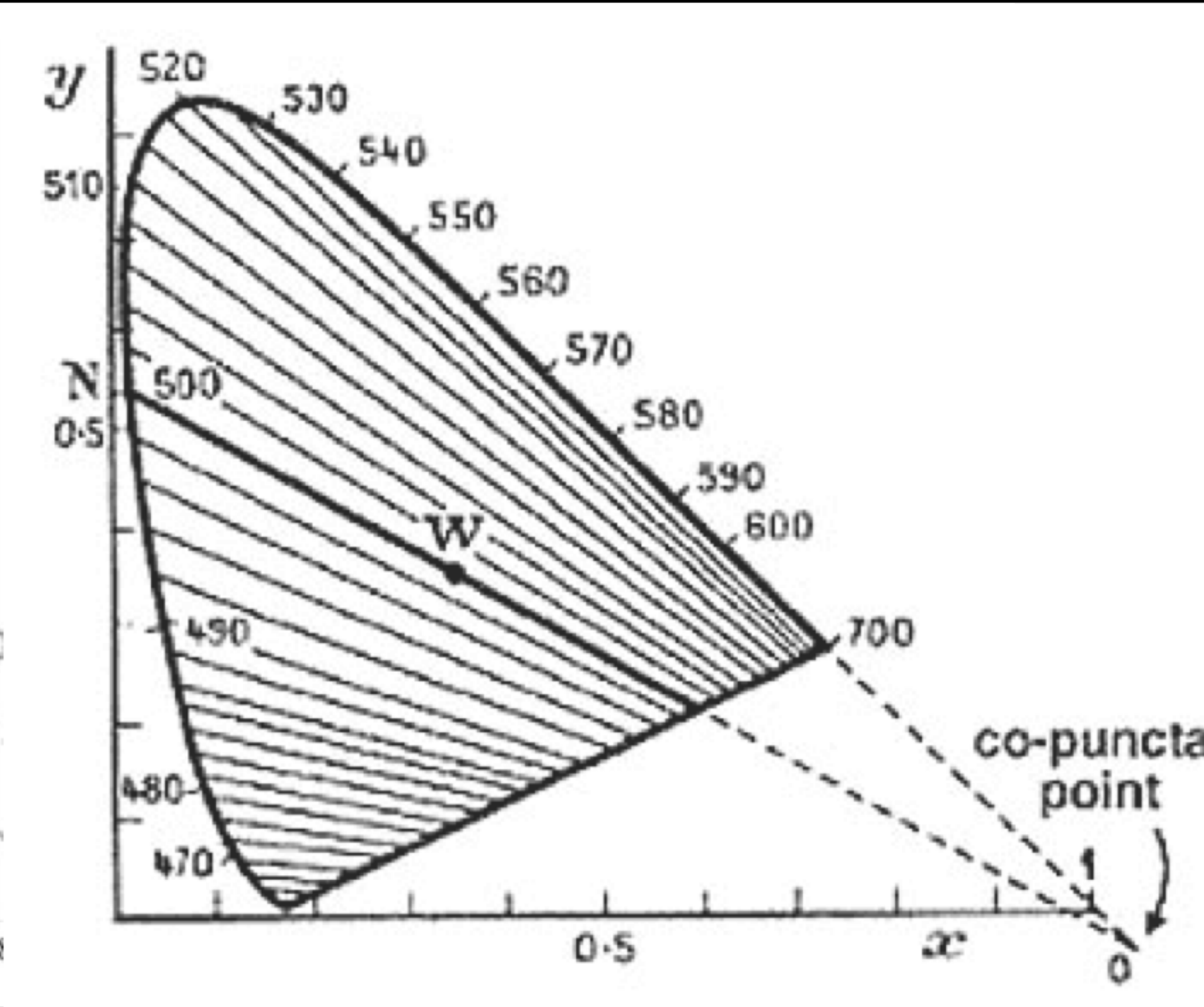
color blindness



Protanopia (red-blind)

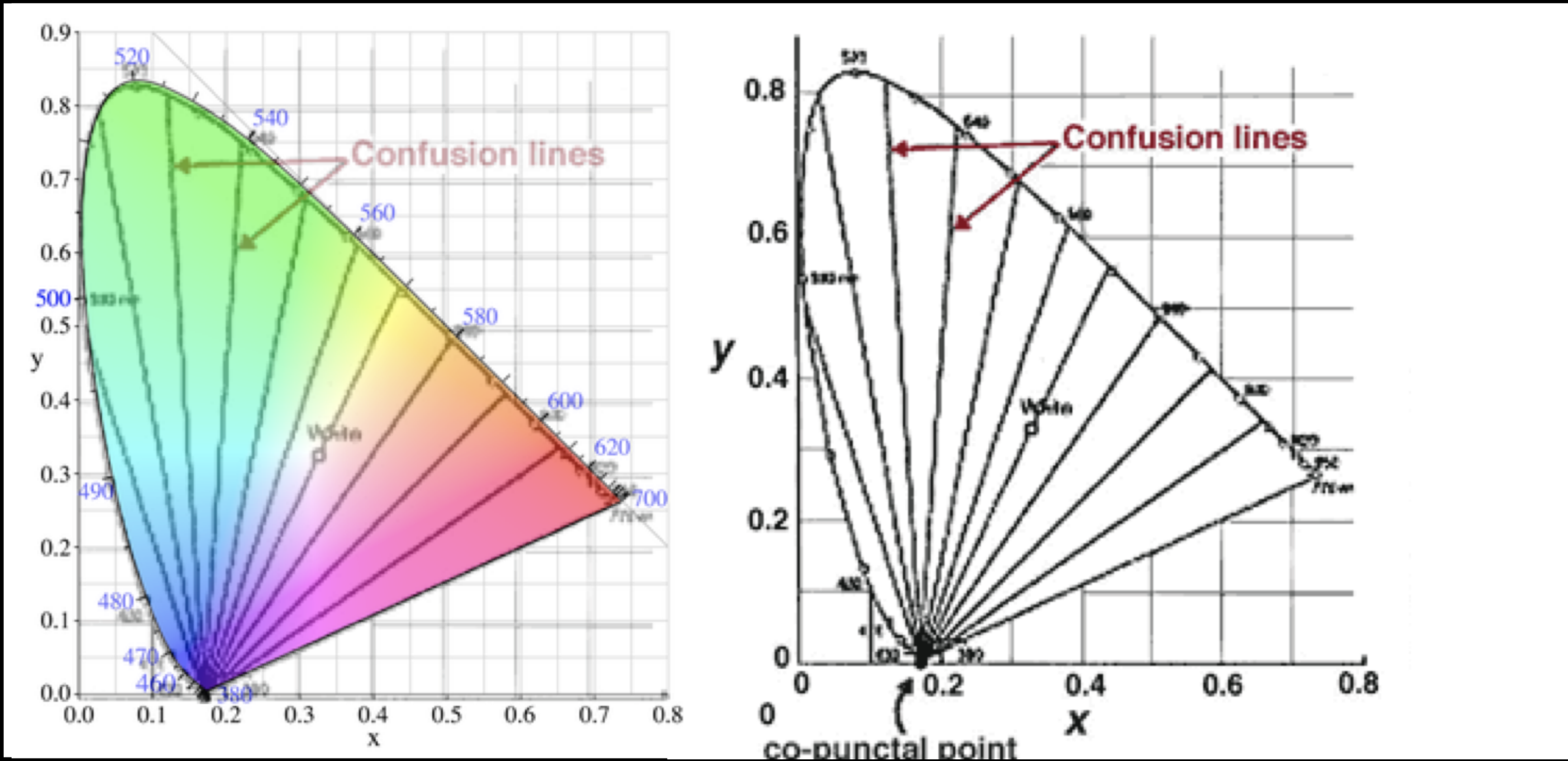
color blindness





Protanopia (green-blind)

color blindness



Tritanopia (blue-blind)

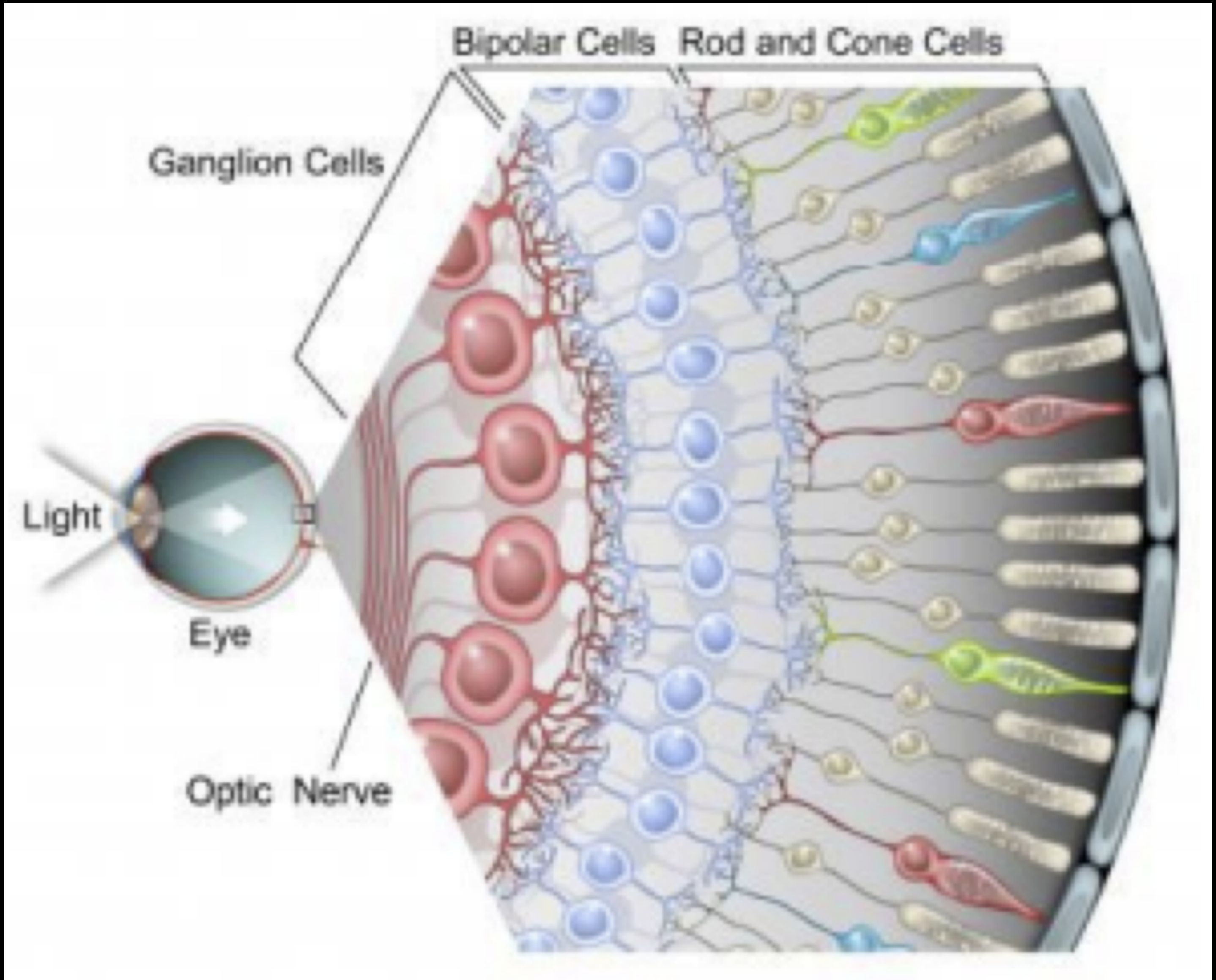
small differences can still be percieved as colors are also associated to brightness

Rods | **Cones**

Brightness | **Color**

R G B

brightness: 31% 59% 10%



http://colororacle.org/

Kelly 1965 designed a list of 22 maximally contrasting colors for colorblind compliance (the “Kelly colors”):

https://medium.com/@rjurney/kellys-22-colours-of-maximum-contrast-58edb70c90d1

TABLE I—COLORS OF MAXIMUM CONTRAST

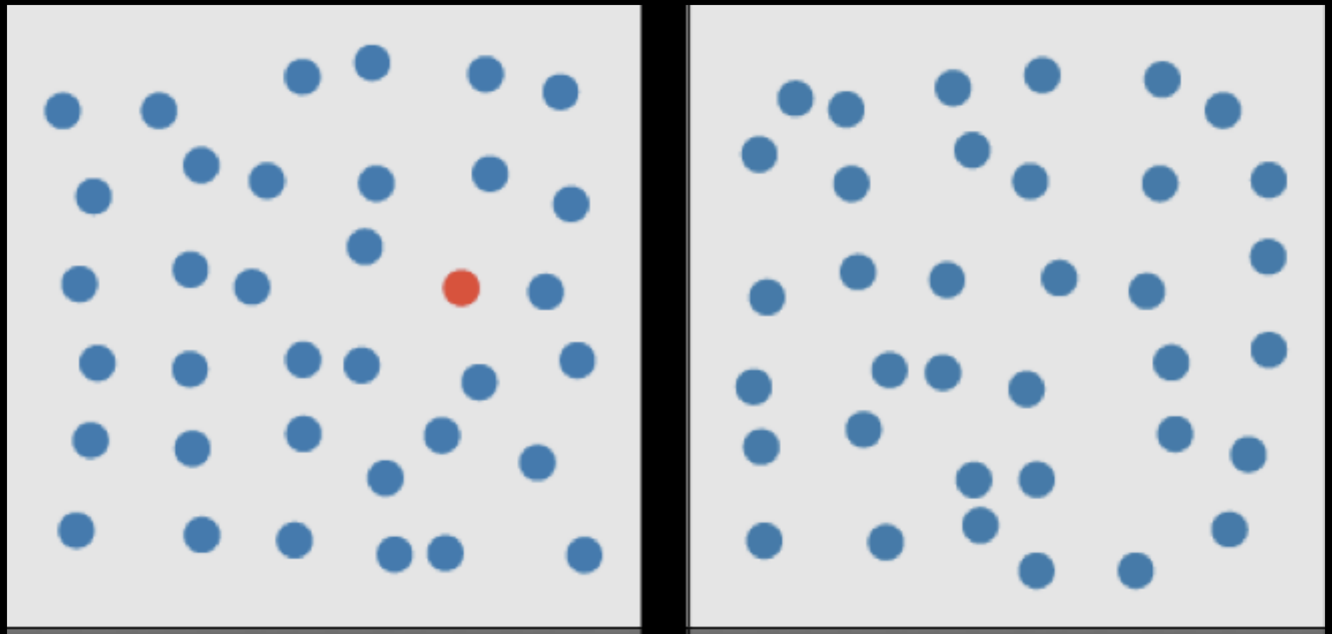
Color Serial or selection number	General color name	ISCC-NBS centroid number	ISCC-NBS color-name (abbreviation)	Munsell renotation of ISCC-NBS Centroid Color
1	white	263	white	2.5PB 9.5/0.2
2	black	267	black	N 0.8/
3	yellow	82	v.Y	3.3Y 8.0/14.3
4	purple	218	s.P	6.5P 4.3/9.2
5	orange	48	v.O	4.1YR 6.5/15.0
6	light blue	180	v.l.B	2.7PB 7.9/6.0
7	red	11	v.R	5.0R 3.9/15.4
8	buff	90	gy.Y	4.4Y 7.2/3.8
9	gray	265	med.Gy	3.3GY 5.4/0.1
10	green	139	v.G	3.2G 4.9/11.1
11	purplish pink	247	s.pPk	5.6RP 6.8/9.0
12	blue	178	s.B	2.9PB 4.1/10.4
13	yellowish pink	26	s.yPk	8.4R 7.0/9.5
14	violet	207	s.V	0.2P 3.7/10.1
15	orange yellow	66	v.OY	8.6YR 7.3/15.2
16	purplish red	255	s.pR	7.3RP 4.4/11.4
17	greenish yellow	97	v.gY	9.1Y 8.2/12.0
18	reddish brown	40	s.rBr	0.3YR 3.1/9.9
19	yellow green	115	v.YG	5.4GY 6.8/11.2
20	yellowish brown	75	deep yBr	8.8YR 3.1/5.0
21	reddish orange	34	v.rO	9.8R 5.4/14.5
22	olive green	126	d.OlG	8.0GY 2.2/3.6

"#023fa5", "#7d87b9", "#bec1d4", "#d6bcc0", "#bb7784", "#8e063b", "#4a6fe3", "#8595e1", "#b5bbe3", "#e6afb9", "#e07b91", "#d33f6a", "#11c638", "#8dd593", "#c6dec7", "#ead3c6", "#f0b98d", "#ef9708", "#0fcfc0", "#9cded6", "#d5eae7", "#f3e1eb", "#f6c4e1", "#f79cd4"

preattentive tasks

https://www.youtube.com/embed/UFNzATczkDU?start=16&enablejsapi=1

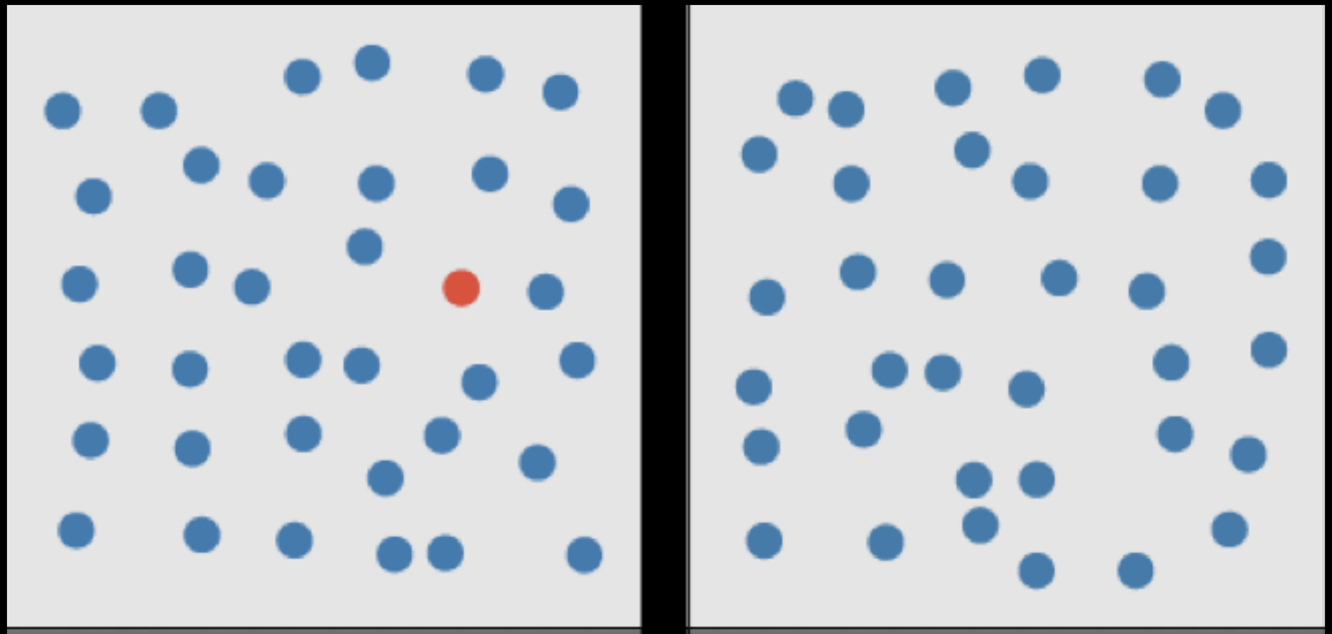
preattentive tasks



a limited set of visual properties that are detected very rapidly and accurately by the low-level visual system.

(tasks that can be performed on large multi-element displays in less than 200 to 250 milliseconds)

preattentive tasks



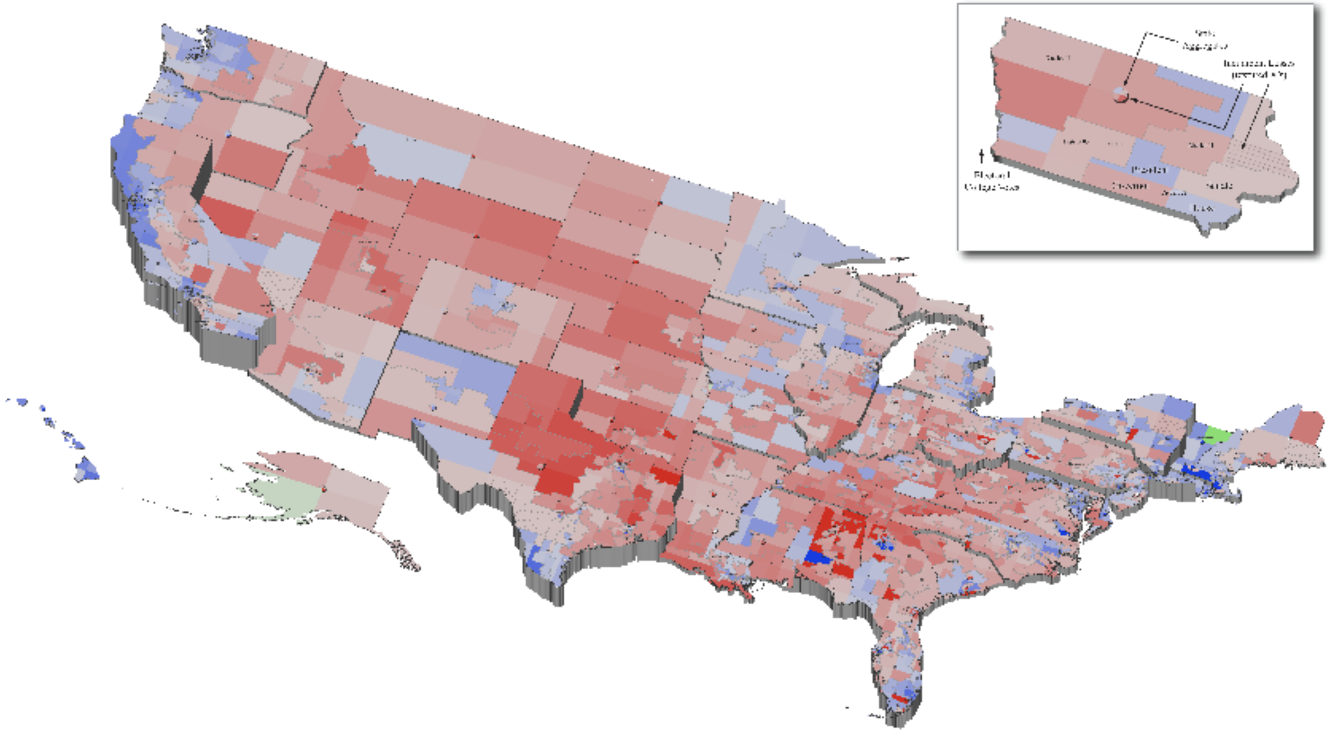
http://www.csc.ncsu.edu/faculty/healey/PP/index.html#jscript_search

how can you leverage preattentive tasks in your vizs

Christopher G. Healey

perceptually-motivated multidimensional visualization of recent U.S. election result

https://www.csc2.ncsu.edu/faculty/healey/PP/



how can you leverage preattentive tasks in your vizs

http://morphocode.com/data-city-urban-visualizations/

how can you leverage preattentive tasks in your vizs

https://www.youtube.com/embed/IGQmdoK_ZfY?enablejsapi=1

don't overdo it.... our brain can miss obvious things if directed to focus on tasks

what makes a good visualization?

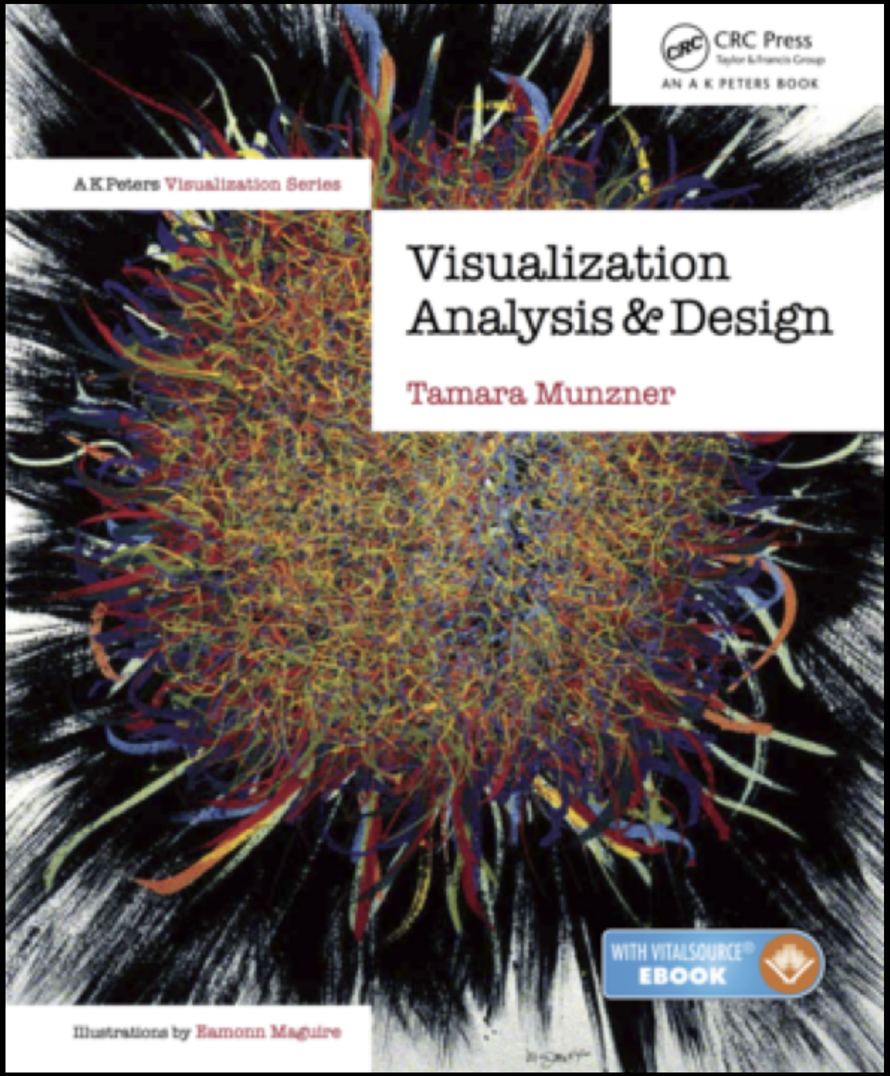
last round, including animation and interactivity:

Tamara Munzner's rules

Rules of thumb for a good visualization

Tamara Munzner

Chapter 6



Function first, Form next

no unjustified beauty

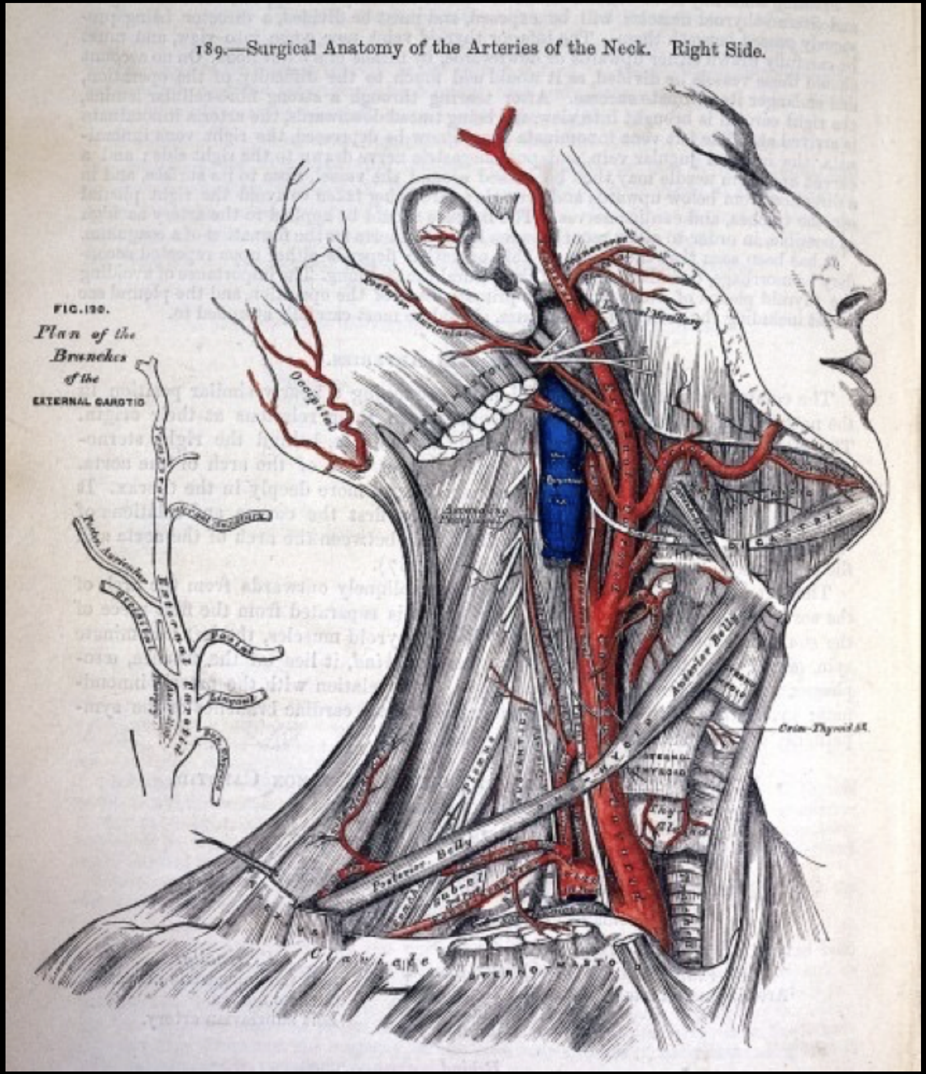
(Tufte's no chart junk)

Get it right in Black & White

no unjustified color

consider designing your plot in BW first

Examples of functional use of color



functional use of color is the standard in anatomy drawings

Häggström, Mikael (2014). "Medical gallery of Mikael Häggström 2014". *WikiJournal of Medicine* **1** (2). DOI:10.15347/wjm/2014.008. ISSN 2002-4436. Public Domain. or *By Mikael Häggström, used with permission.* - Image:Gray507.png

Examples of functional use of color (and distortion)

MTA NYC subway map

functional use of color

functional use of deformation

(the boroughs' size is changed to make the distance between subway stops similar.

but consider the psychological and social implications of blowing up Manhattan...

No Unjustified 3D

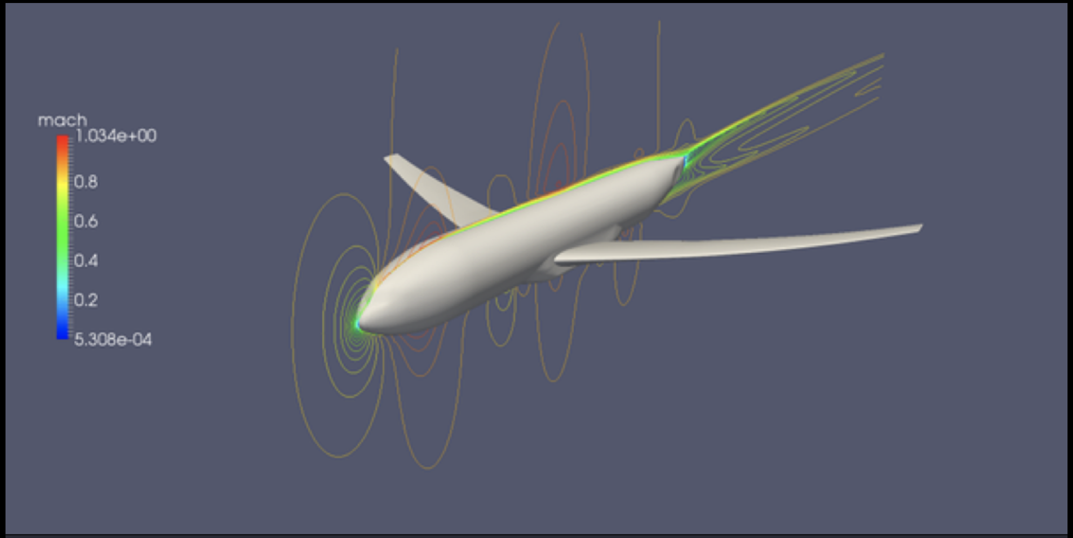
use 3D only if your 3rd dimention cannot be reduced.

Alternatives:

color,

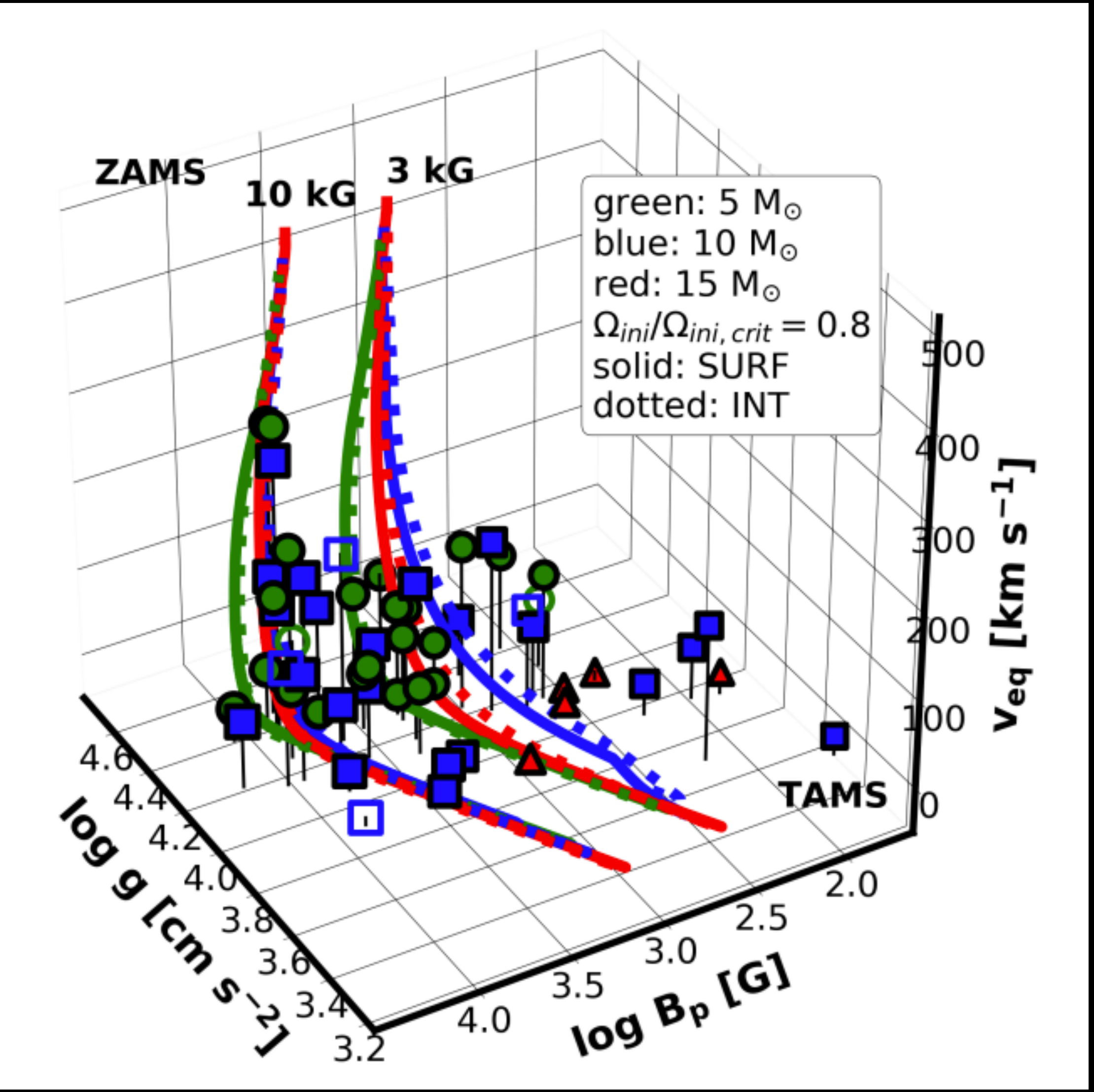
small multiples,

animation



from Tamara Munzner chapter 6

No Unjustified 3D



from private communication...

obstruction

clutter

deformation

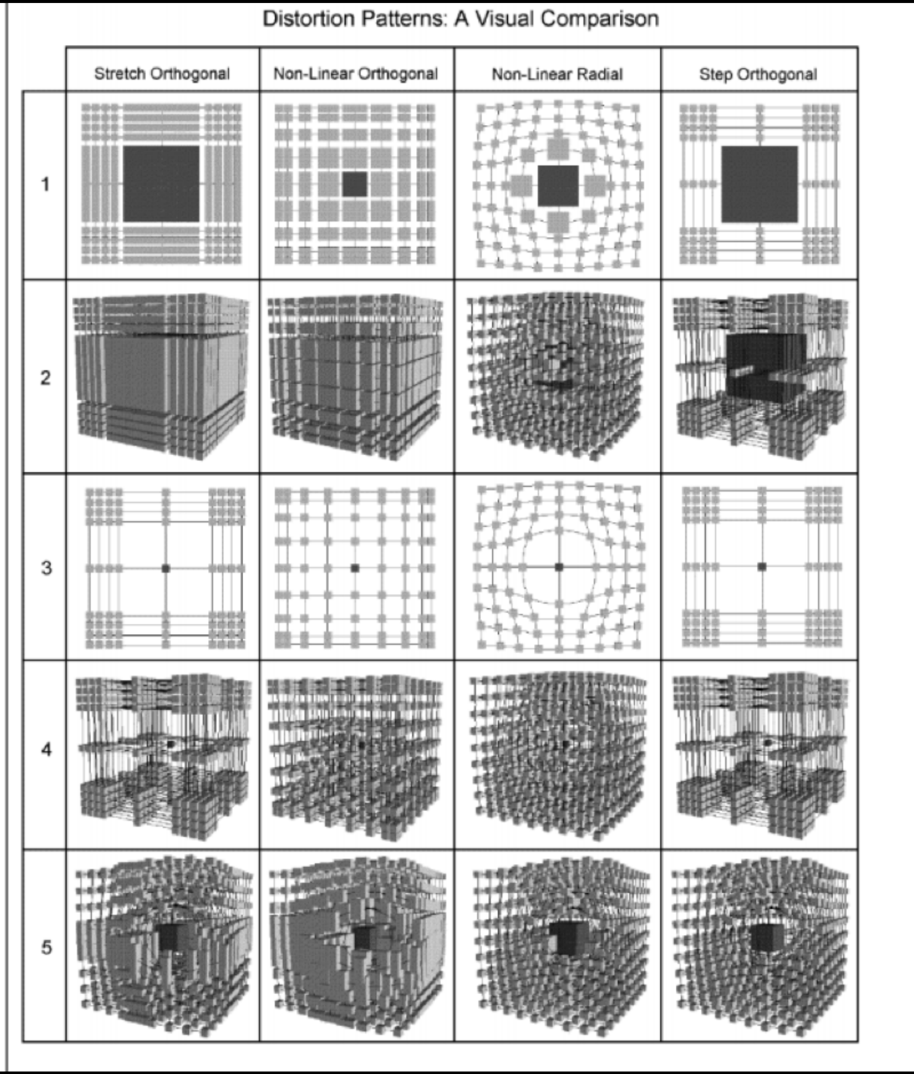
No Unjustified 3D

distortion

techniques

to overcome obstruction

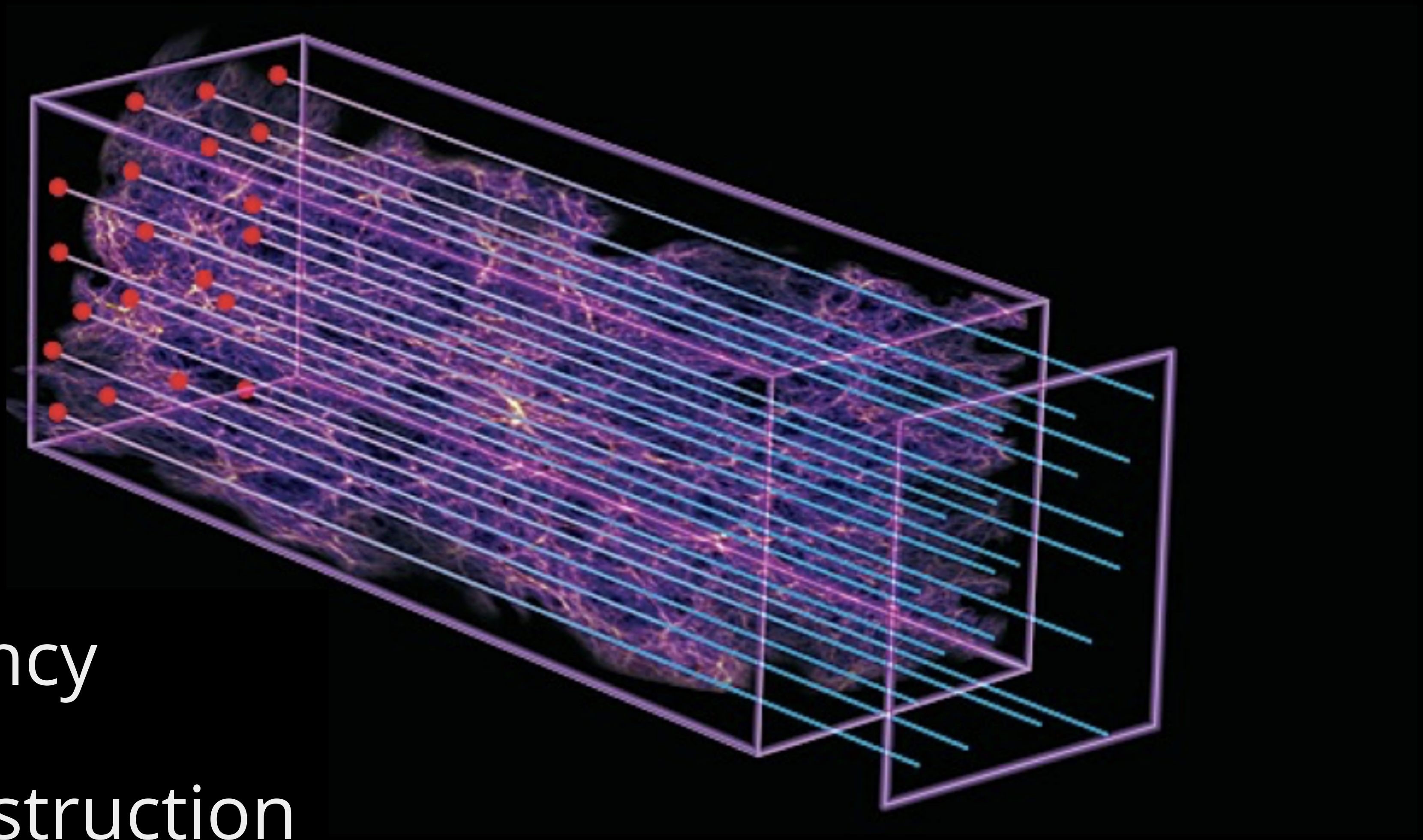
downside: distortion, clutter



3 This chart presents visually the effect of different distortion techniques on spatial organization.

from Tamara Munzner chapter 6

No Unjustified 3D

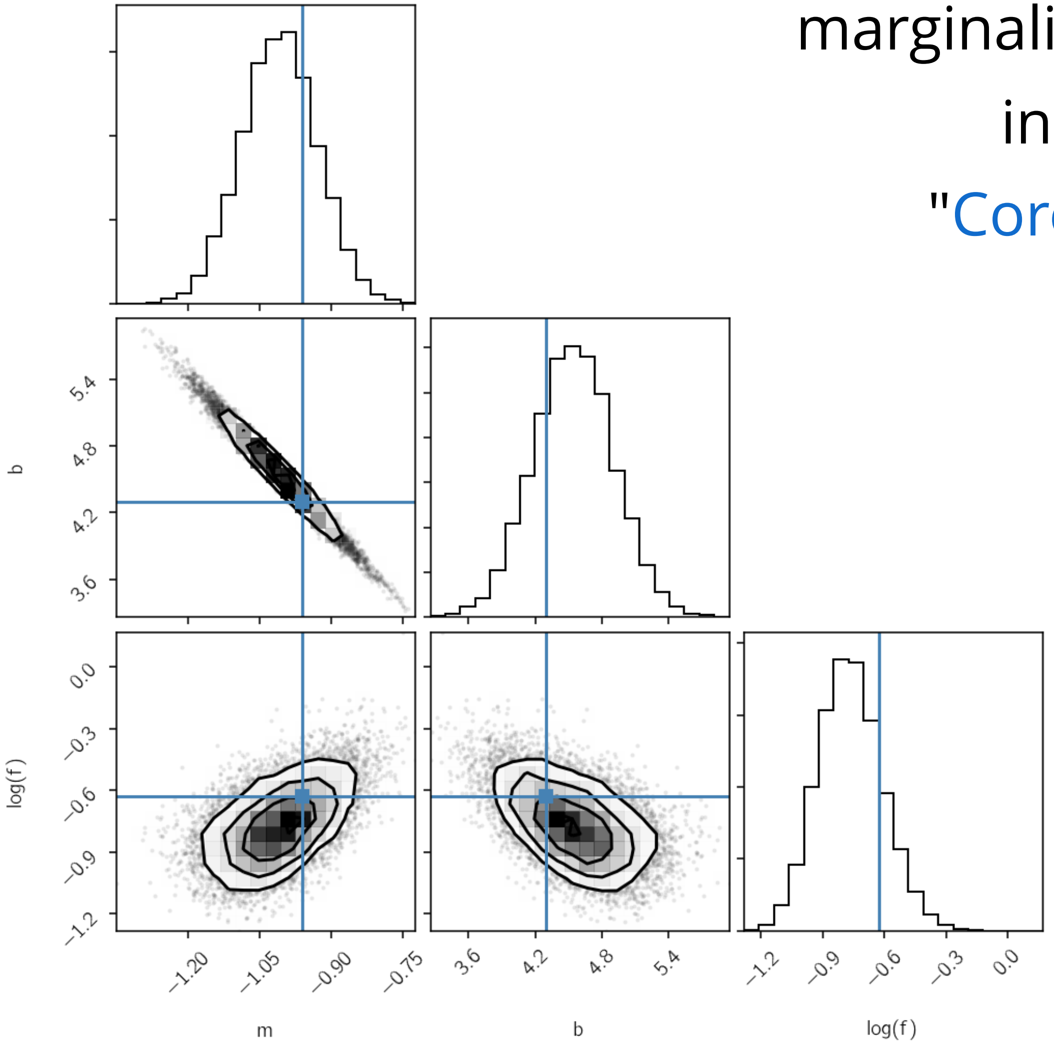


transparency

to overcome obstruction

Zosia Rostomian, LBNL; Nic Ross, BOSS Lyman-alpha team, LBNL; and Springel et al, Virgo Consortium and the Max Planck Institute for Astrophysics

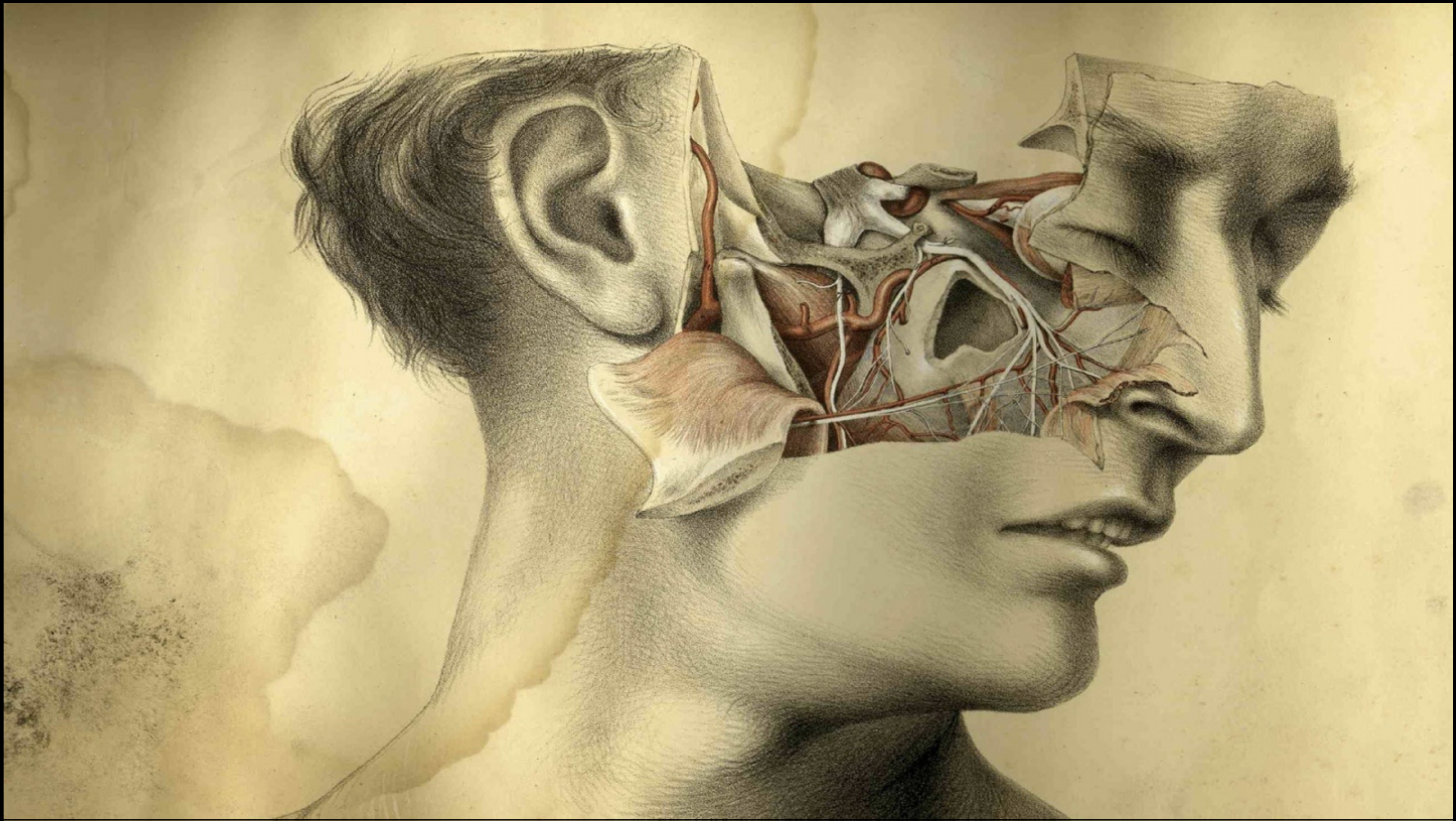
No Unjustified 3D



marginalized posteriors

in MCMC

"Corener Plot"



No Unjustified 3D

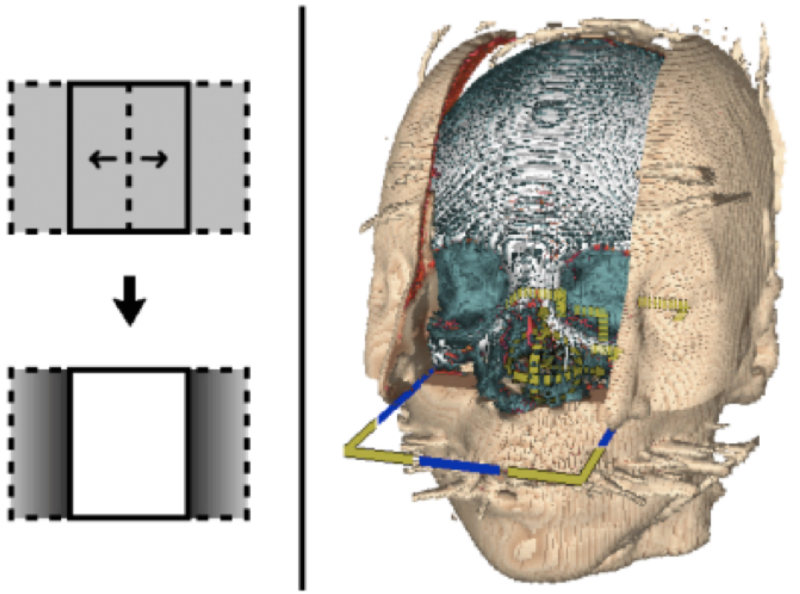


Figure 3.11: The Box Spreader. Left: voxels before and after deformation. All voxels contained in the box are pushed sideways, compressing surrounding voxels that are within twice the box's width. Right: the Box Spreader, acting only on layers outside the skull, cuts the upper face in half and pushes each half off the skull.

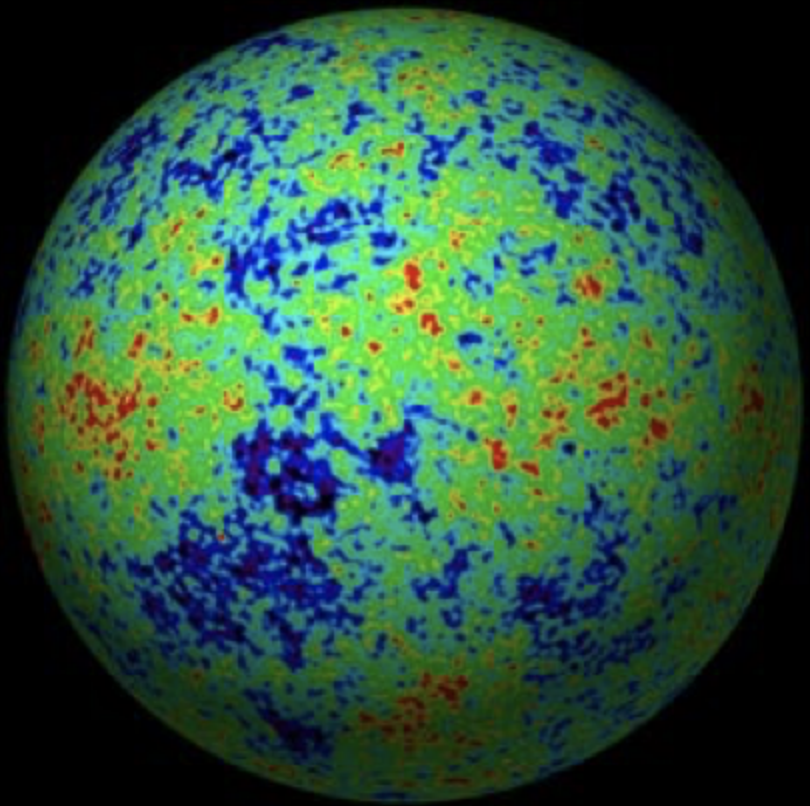
Anatomical drawing style deals with obstruction while preserving the context

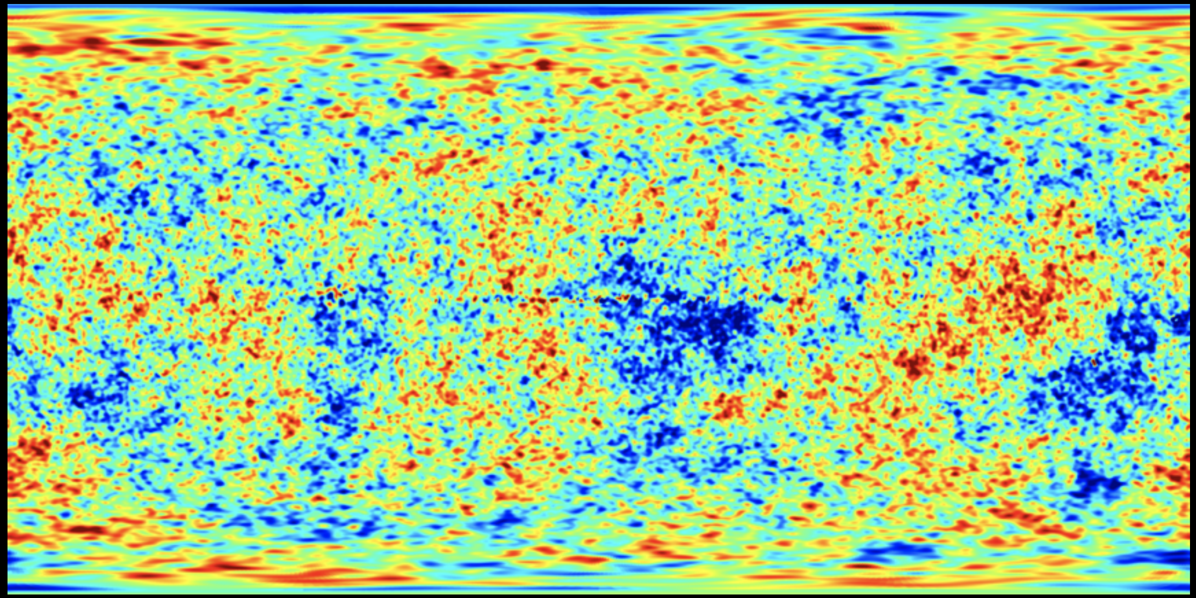
An Investigation of Issues and Techniques in

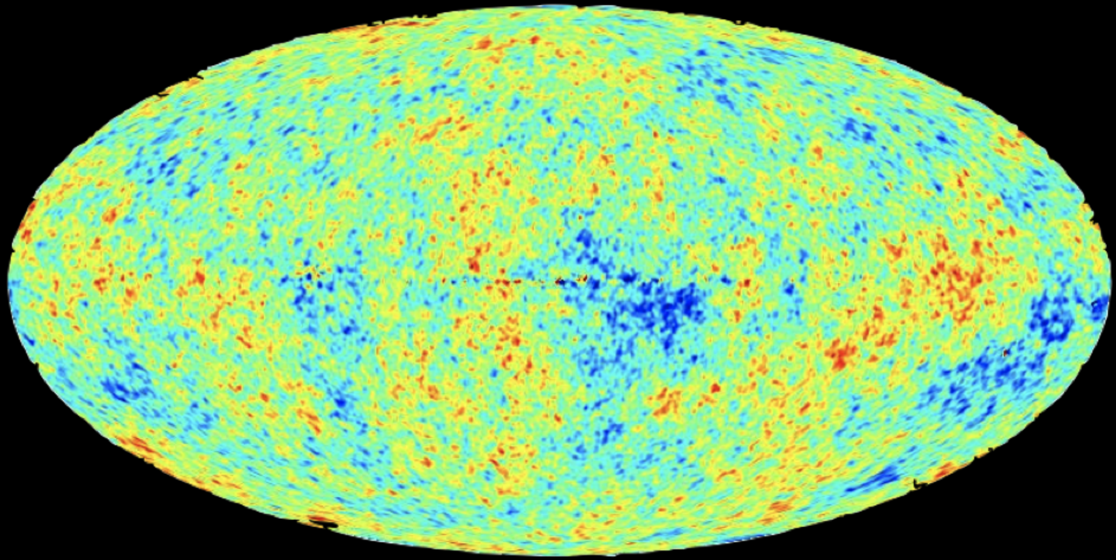
Highly Interactive Computational Visualization

Michael John MCGuffin

No Unjustified 3D







Visualizing highly dimensional data: consider animation if you can!

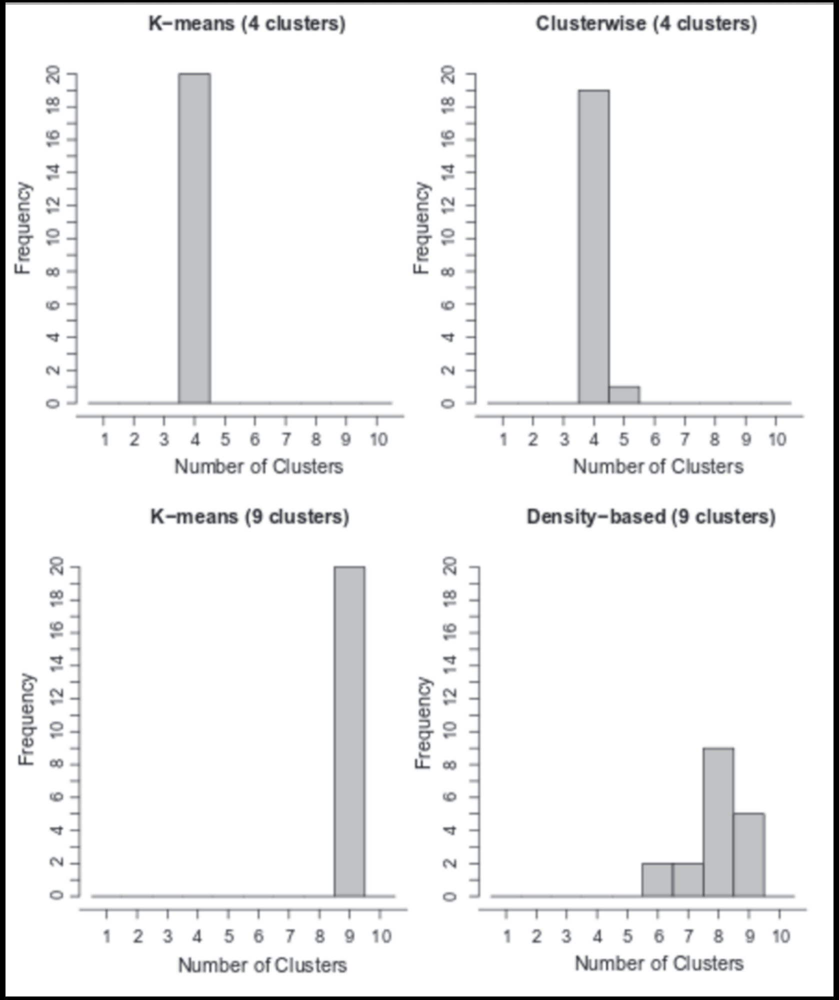
https://www.youtube.com/embed/jgO0JU_l5-s?enablejsapi=1

The astronomical event broker Antares, G. Narayan

Also:

No Unjustified 2D!

Also:
No Unjustified 2D!



Eyes over Memory

no unjustified animation

https://www.youtube.com/embed/FWVDi4aKC-M?
enablejsapi=1

Eyes over Memory

no unjustified animation

Interactivity

interactive visualization rules of thumb:

Resolution over immersion

Interactivity

interactive visualization rules of thumb:

Resolution over immersion

Details on demand

Interactivity

interactive visualization rules of thumb:

Resolution over immersion

Details on demand

Avoid latency

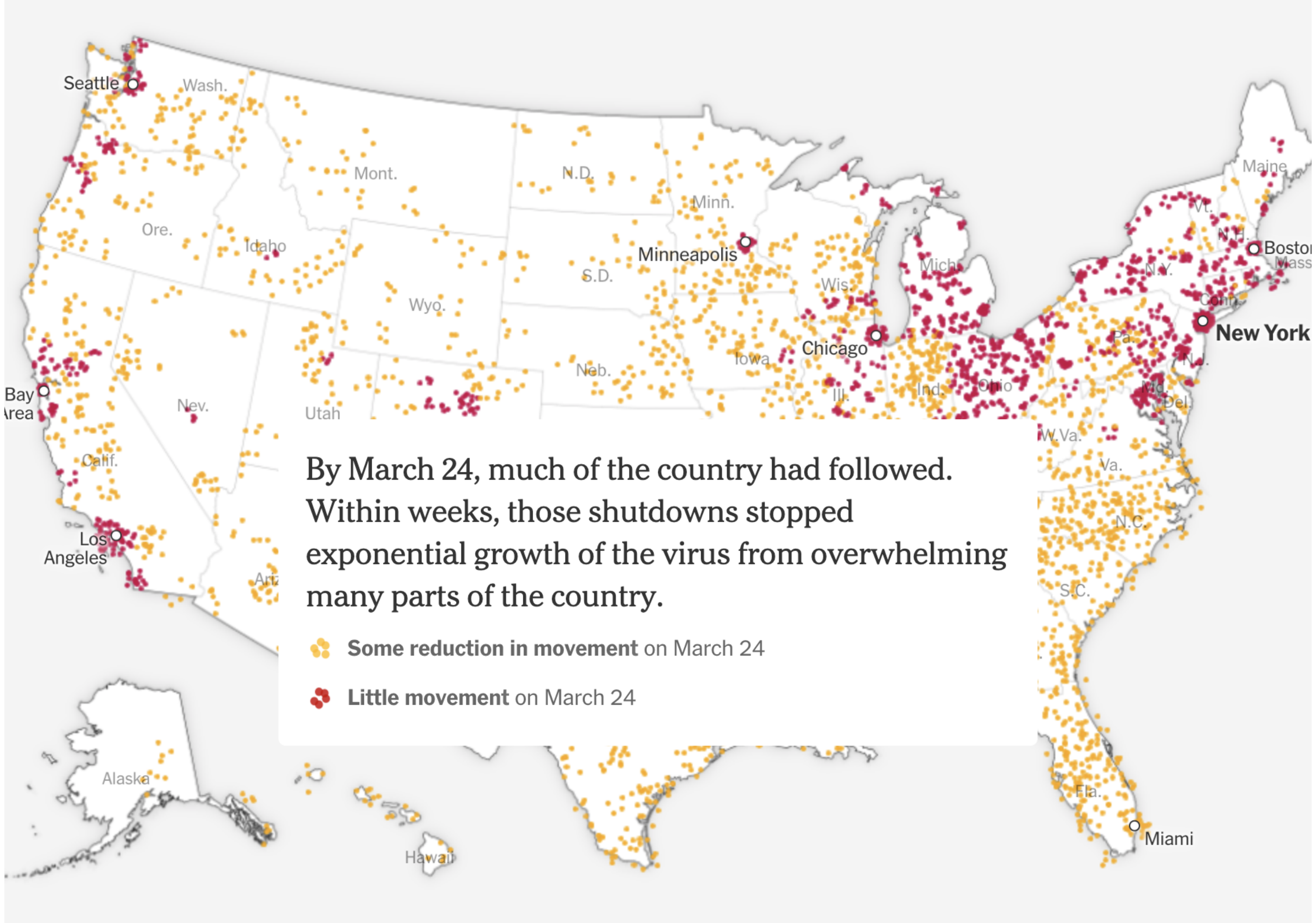
Interactivity

interactive visualization rules of thumb:

use animation/interactivity to allow switching between a comprehensive global view and a detailed reducted view

https://lsst-tvssc.github.io/TVSaffiliations/

Interactivity

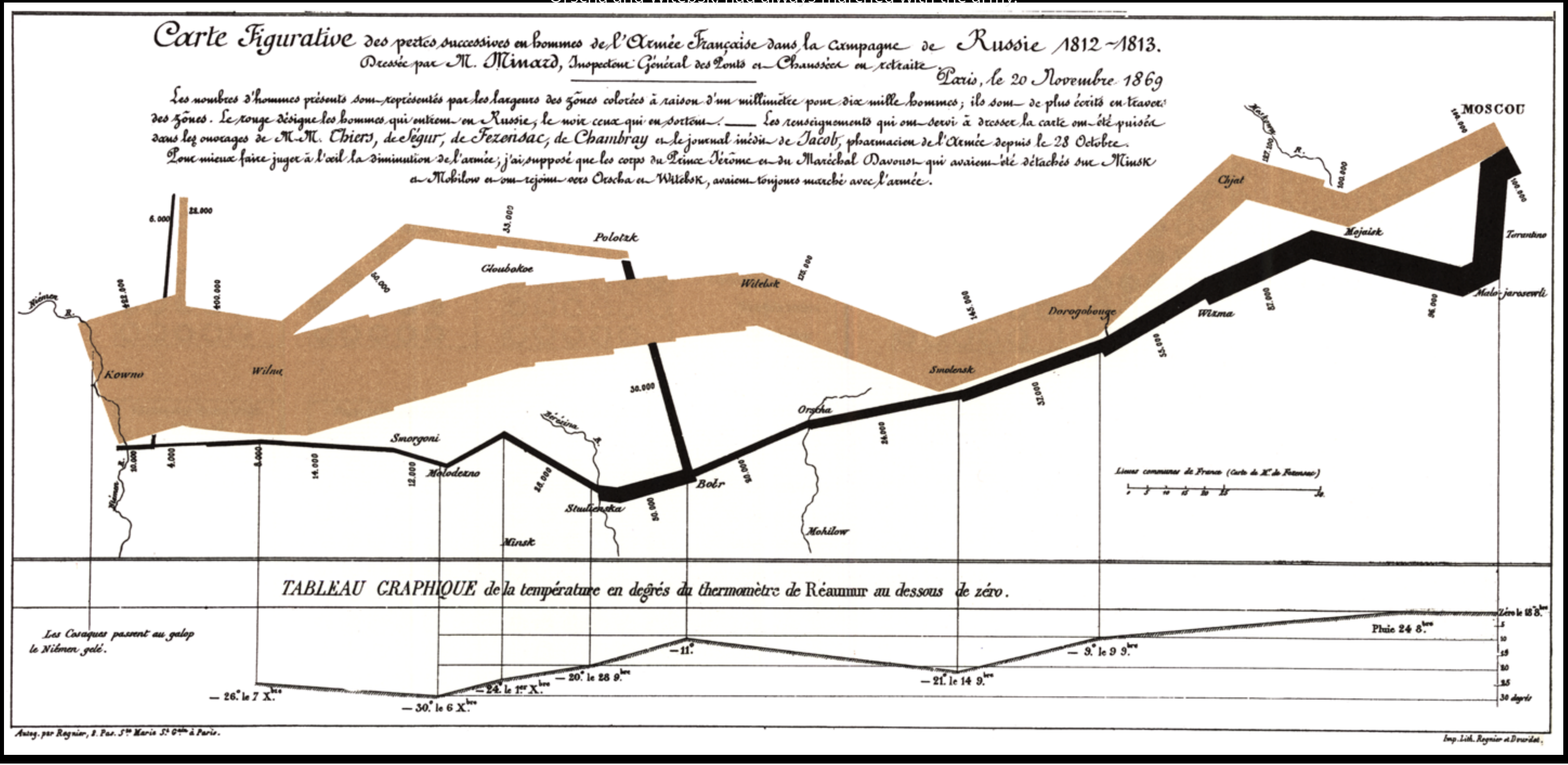


https://www.nytimes.com/interactive/2020/us/coronavirus-spread.html

Minard's russian campaign : so why is this plot so good?

Figurative Map of the successive losses in men of the French Army in the Russian campaign 1812-1813.

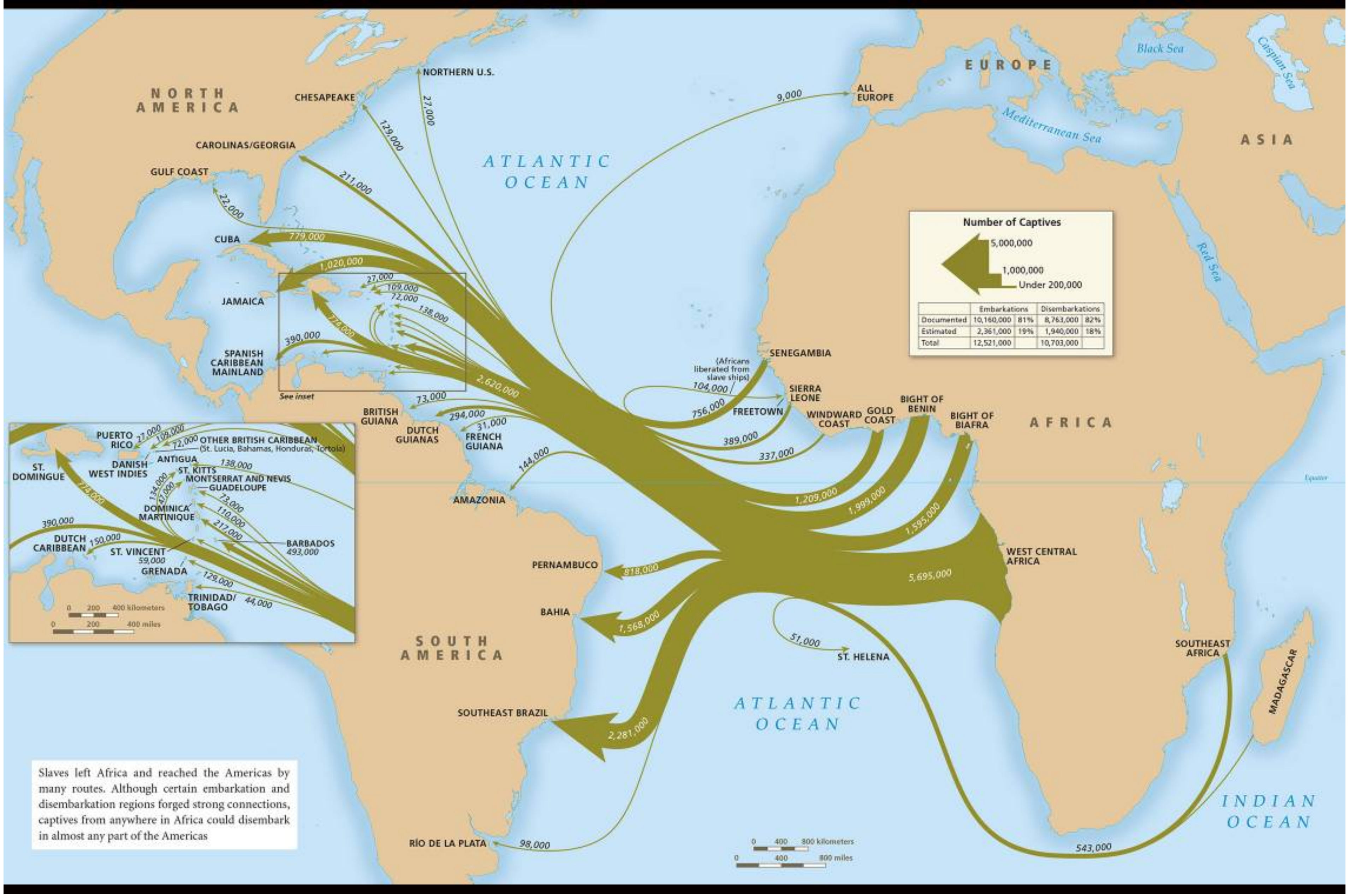
The numbers of soldiers present are represented by the widths of the colored zones in a rate of one millimeter for ten thousand soldiers; these are also written beside the zones. Red designates men moving into Russia, black those on retreat. — The information used for drawing the map were taken from the works of Messrs. Chiers, de Ségur, de Fezensac, de Chambray and the unpublished diary of Jacob, pharmacist of the Army since 28 October. In order to facilitate the judgement of the eye regarding the diminution of the army, I supposed that the troops under Prince Jèrôme and under Marshal Davoust, who were sent to Minsk and Mobilow and who rejoined near Orscha and Witebsk, had always marched with the army.



so there is a thing called "the rule of 7": you cannot put more than 7 pieces of information in your plot because that his the maximum number of things a person can remember. Well, that 7 comes from a test where people are told several words and asked to repeat them back. On average people remember 7... +/-4 ...

The number of information elements that are shown in a plot depends on how effectively you can show them. This plot contains (at least) the following features:
space (distance, however approximate), time, size of the army, rate of lives lost (highly covariant with size of the army), purpose (going on the attack toward Moskow or retreating, indicated by the color), topography (changes of direction, rivers), temperature, the last 2 are conveying a causal connection by showing the lives lost (decrease in width of the army size) in conjunction with critical temperatures and rivers)

Tufte's rules	lie factor=1, data/ink ratio high, no chart junk, #graphical elements ~ #features
Munzner's rules	functional use of color, no unjustified 3D, eyes over memory (granted.... they did not have animations back then)



a similar visualization for the Black diaspora

Map of slave-trade voyages across the Atlantic.

(Emory Center for Digital Scholarship, Mellon Foundation)

key concepts

Be thoughtful and make sure your visualizations are (in this order):

honest

clear

convincing

beautiful

key concepts

Identify the purpose of your visualization:

visualize to communicate results

visualize to understand data and guide analysis

Edwaed tufte (anything)

Wassily Kandinsky, *Point, Line, and Plane,* 1926

Tamara Munzner

Visualization Analysis & Design, 2014

(link to a talk slide-deck about her book:
http://www.cs.ubc.ca/~tmm/talks/minicourse14/vad15london.pdf)

color maps http://www.kennethmoreland.com/color-maps/

Kelly colors https://medium.com/@rjurney/kellys-22-colours-of-maximum-contrast-58edb70c90d1

resources

7 Great Visualizations from History

https://web.archive.org/web/20171114145335/http://data-informed.com/7-great-visualizations-history/

7 classical vis papers

https://web.archive.org/web/20190226213626/http://fellinlovewithdata.com/guides/7-classic-foundational-vis-papers

Six Lessons from the Bauhaus: Masters of the Persuasive Graphic

http://blog.visual.ly/six-lessons-from-the-bauhaus-masters-of-the-persuasive-graphic/

Using preattemptive processing elements

https://pdfs.semanticscholar.org/0456/bc9cdf02c3a446e252cf2e6b83145e17749a.pdf

resources

This:

How W.E.B. Du Bois Meticulously Visualized 20th-Century Black America

https://hyperallergic.com/476334/how-w-e-b-du-bois-meticulously-visualized-20th-century-black-america/

And any of these papers:

7 classical vis papers

https://web.archive.org/web/20190226213626/http://fellinlovewithdata.com/guides/7-classic-foundational-vis-papers

reading

View this:

https://www.youtube.com/watch?v=Q9wcvFkWpsM&app=desktop

TEDxVancouver - Jer Thorp - The Weight of Data

Create a plot, of whatever data (and models if you want) you choose from open data (if you have doubt about whether your dataset is relevant for this homework please email me.)

You can make the plot in any coding language you want (e.g. python, javascript, R...), as long as you upload the code that generates the plot onto your repo (which means no tableau, or any other non reproducible).

If it is a redesign of a plot you already made (e.g. for your research) upload the original as well

The plot needs to be uploaded onto the HW9 folder in your github PUS2020 repo and be embedded in the README.md That means: when I click on the HW9 link the plot must be rendered in the front page of the repo. Your readme must contain the plot, and a brief caption. If it is an interactive graphic, upload a static image of it in the README and provide a link to the interactive version.

Think about all the considerations we have made about visualization in the last 3 classes.