

Information Visualization Crash Course

(AKA Information Visualization 101)

Dr. Chad Stolper
Now at Google
Georgia Tech CS PhD Alum



What is Infovis?
Why is it Important?
Human Perception
Chart Basics

(If Time, Some Color Theory)

The Shneiderman Mantra
Where to Learn More

What is Information Visualization?

Information Visualization

“The use of **computer**-supported, **interactive**, **visual** representations of abstract data to **amplify cognition**.”

Card, Mackinlay, and Shneiderman 1999

Communication

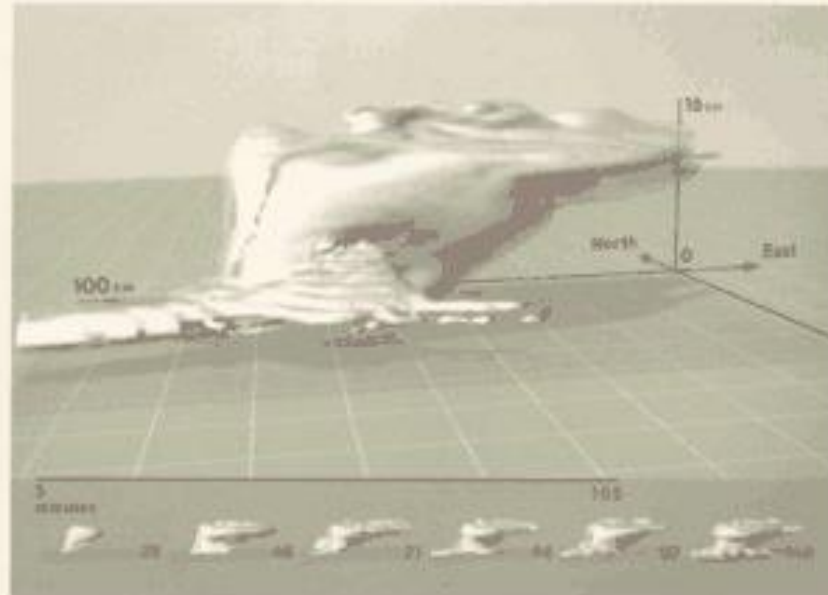
Exploratory Data Analysis (EDA)

Communication

(gone wrong)

EDWARD R. TUFTE

VISUAL EXPLANATIONS



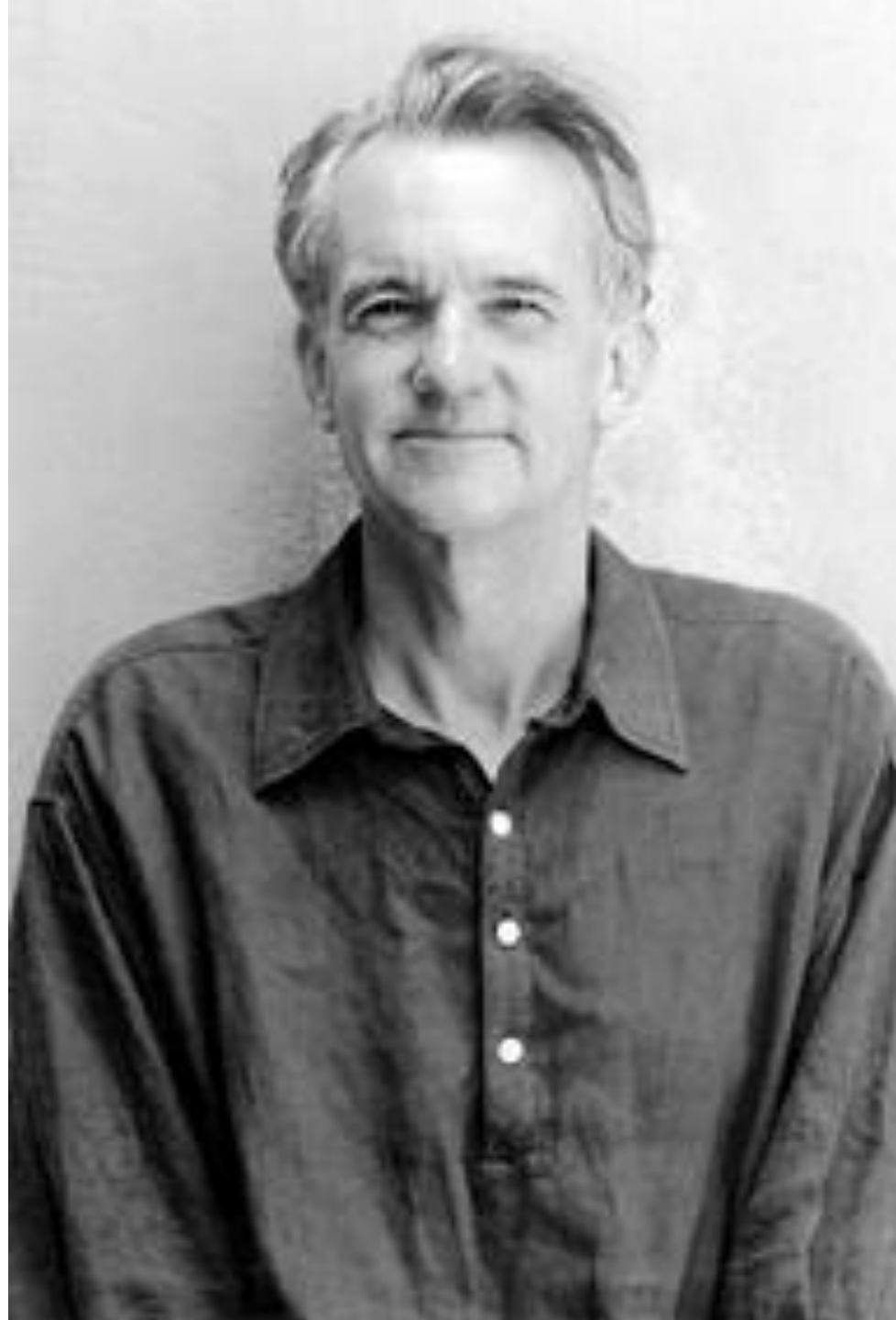
IMAGES AND QUANTITIES, EVIDENCE AND NARRATIVE

Edward Tufte

An American statistician and professor emeritus of political science, statistics, and computer science at Yale University.

He is noted for his writings on information design and as a pioneer in the field of data visualization.

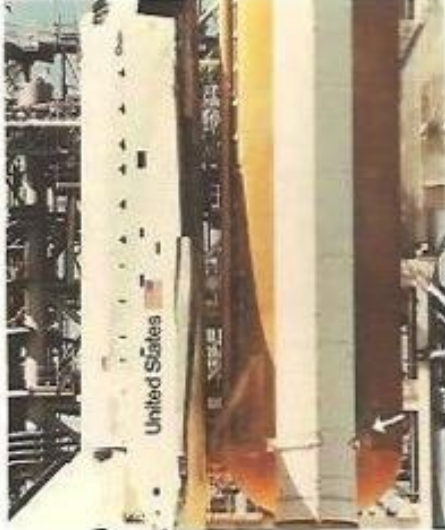
-Wikipedia



Space Shuttle Challenger

January 28, 1986

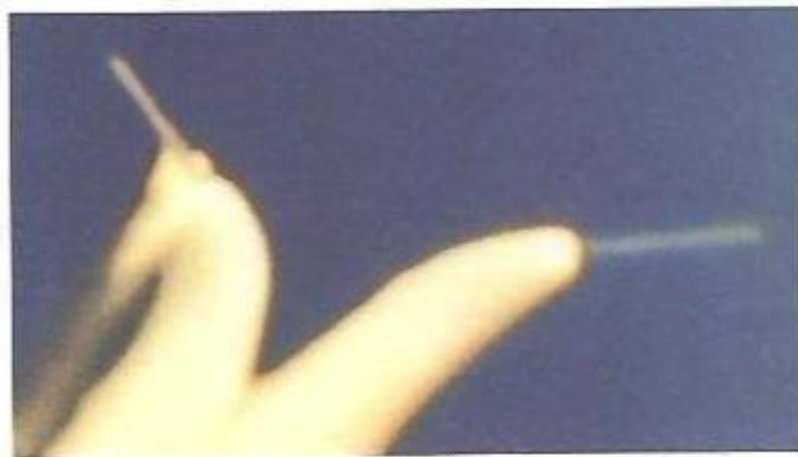
Morning Temperature: 31°F



Less than 1 second after ignition, a puff of smoke appeared at the aft joint of the right booster, indicating that the O-rings burned through and failed to seal. At this point, all was lost.



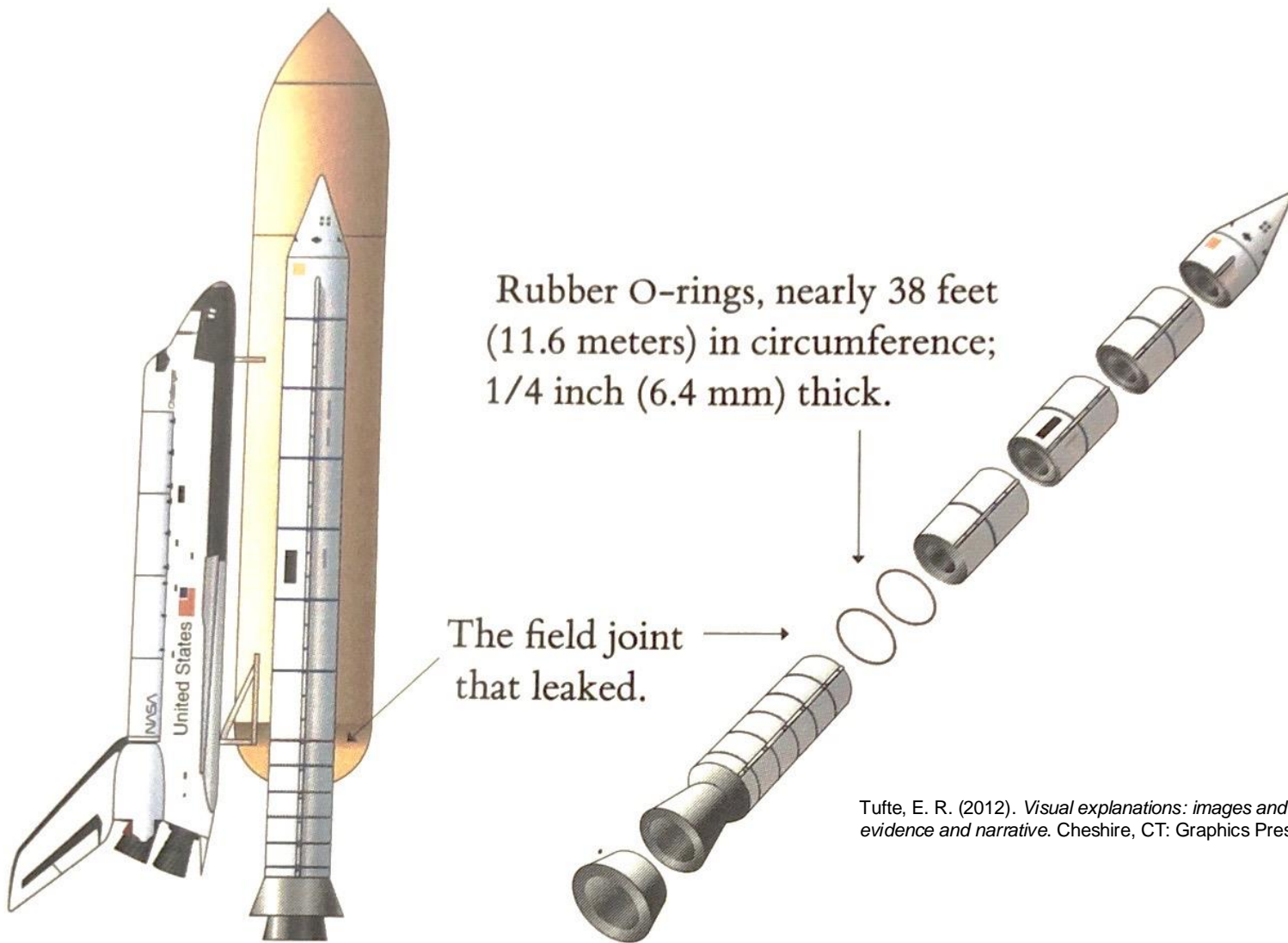
On the launch pad, the leak lasted only about 2 seconds and then apparently was plugged by and insulation as the shuttle rose, flying through rather strong cross-winds. Then 58.788 seconds after ignition, when the Challenger was 6 miles up, a flicker of flame emerged from the leaky joint. In 15 seconds, the flame grew and engulfed the fuel tank (containing liquid hydrogen and liquid oxygen). That tank ruptured and exploded, destroying the shuttle.



As the shuttle exploded and broke up at approximately 73 seconds after launch, the two booster rockets crisscrossed and continued flying wildly. The right booster, identifiable by its failure plume, is now to the left of its non-defective counterpart.



The flight crew of Challenger 51-L. Front row, left to right: Smith, pilot; Francis R. (Dick) Scobee, commander; Ronald McNair. Back row: Ellison S. Onizuka, S. Christa McAuliffe, Gregory B. Jarvis, Judith A. Resnik.



Tufte, E. R. (2012). *Visual explanations: images and quantities, evidence and narrative*. Cheshire, CT: Graphics Press.

Most Watched Science Experiment

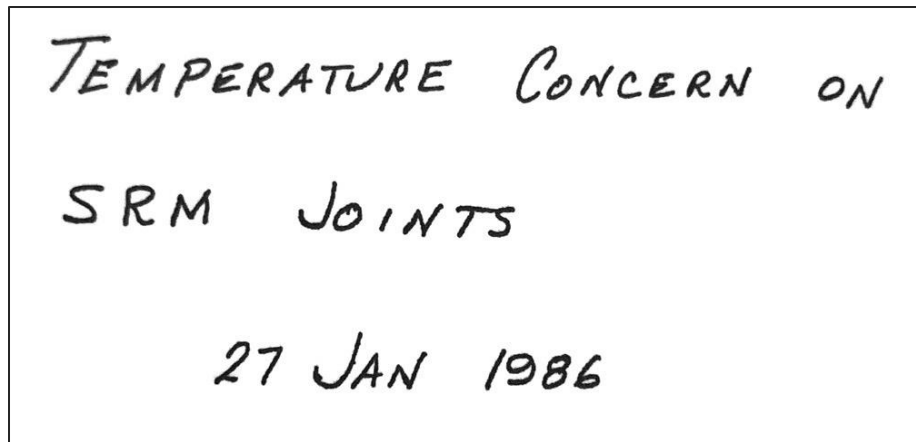


Richard Feynman, Physics Nobel laureate explained how rubber became rigid in cold temperate

YouTube video:
<https://youtu.be/6Rwcbsn19c0>

How did this happen?

Engineers at **Morton Thiokol**, the rocket maker, presented on the day before and recommended **not to launch**.



TEMPERATURE CONCERN ON
SRM JOINTS
27 JAN 1986

CONCLUSIONS :

- TEMPERATURE OF O-RING IS NOT ONLY PARAMETER CONTROLLING BLOW-BY

SRM 15 WITH BLOW-BY HAD AN O-RING TEMP AT 53°F
SRM 22 WITH BLOW-BY HAD AN O-RING TEMP AT 75°F
FOUR DEVELOPMENT MOTORS WITH NO BLOW-BY
WERE TESTED AT O-RING TEMP OF 47° TO 52°F

DEVELOPMENT MOTORS HAD PUTTY PACKING WHICH
RESULTED IN BETTER PERFORMANCE

- AT ABOUT 50°F BLOW-BY COULD BE EXPERIENCED IN CASE JOINTS
- TEMP FOR SRM 25 ON 1-26-86 LAUNCH WILL BE 29°F 9AM
38°F 2PM
- HAVE NO DATA THAT WOULD INDICATE SRM 25 IS DIFFERENT THAN SRM 15 OTHER THAN TEMP

RECOMMENDATIONS :

- O-RING TEMP MUST BE $\geq 53^\circ\text{F}$ AT LAUNCH

DEVELOPMENT MOTORS AT 47° TO 52°F WITH
PUTTY PACKING HAD NO BLOW-BY
SRM 15 (THE BEST SIMULATION) WORKED AT 53°F

- PROJECT AMBIENT CONDITIONS (TEMP & WIND)
TO DETERMINE LAUNCH TIME

RECOMMENDATIONS :

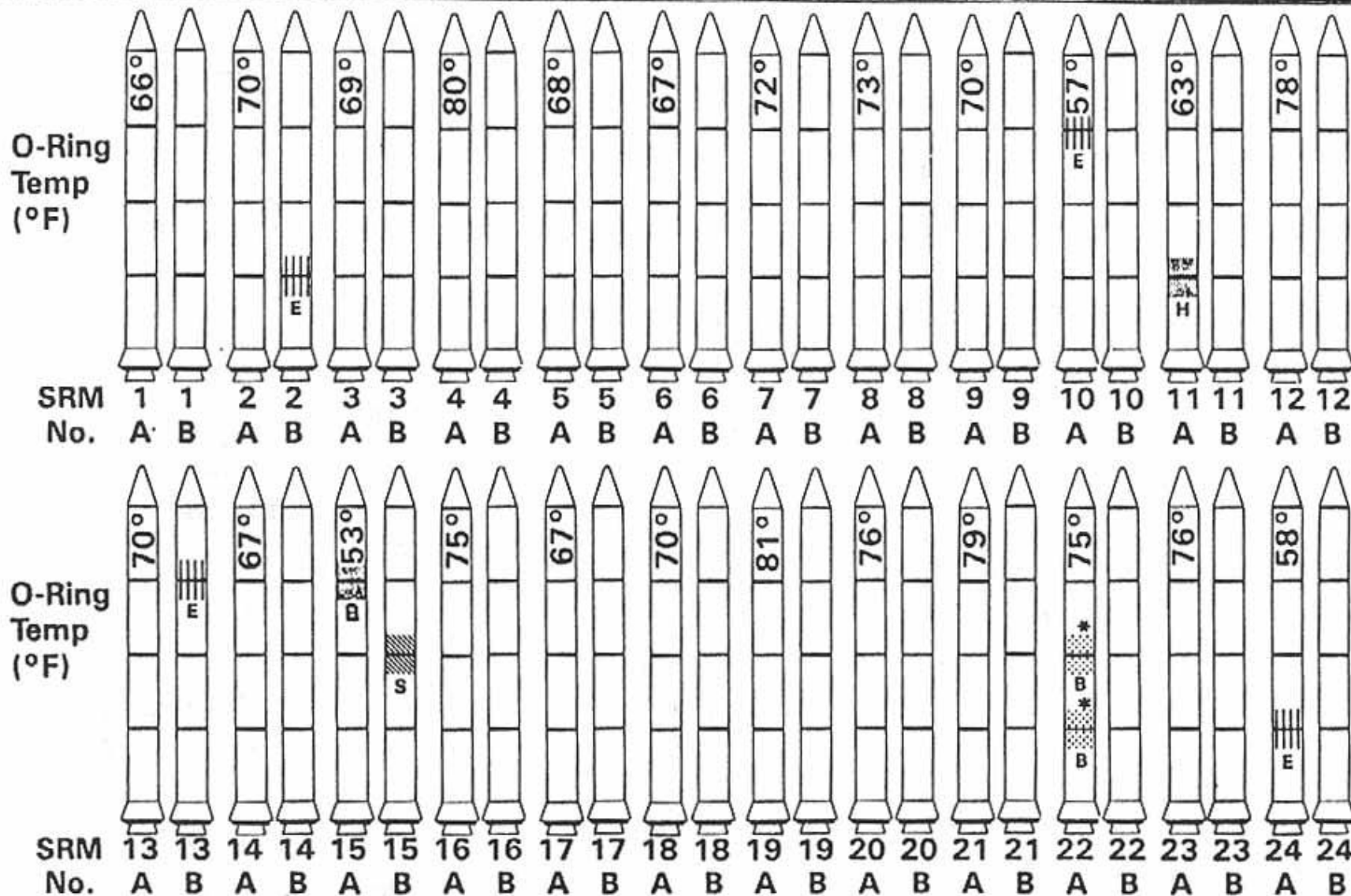


- O-RING TEMP MUST BE $\geq 53^\circ\text{F}$ AT LAUNCH

DEVELOPMENT MOTORS AT 47° TO 52°F WITH
PUTTY PACKING HAD NO BLOW-BY
SRM 15 (THE BEST SIMULATION) WORKED AT 53°F

- PROJECT AMBIENT CONDITIONS (TEMP & WIND)
TO DETERMINE LAUNCH TIME

History of O-Ring Damage in Field Joints (Cont)



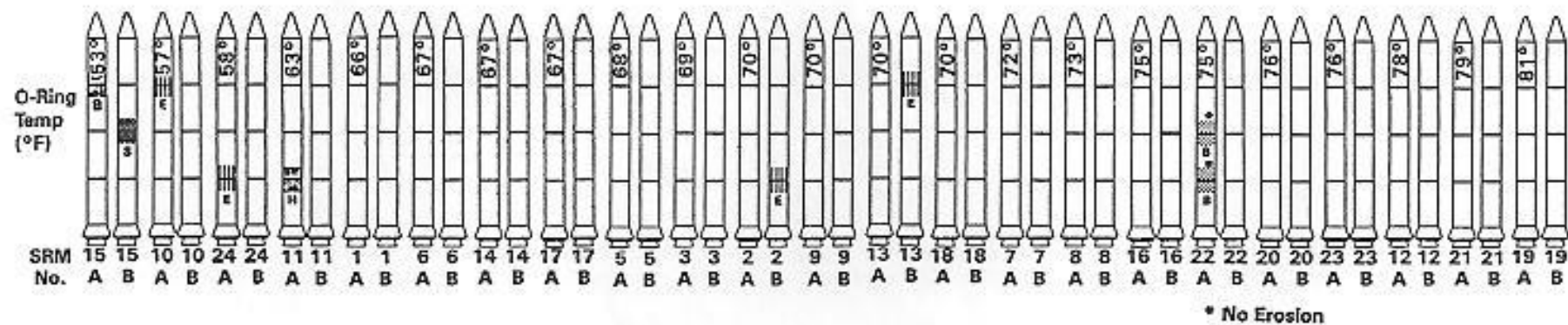
MORTON THIOKOL, INC.
Wasatch Operations

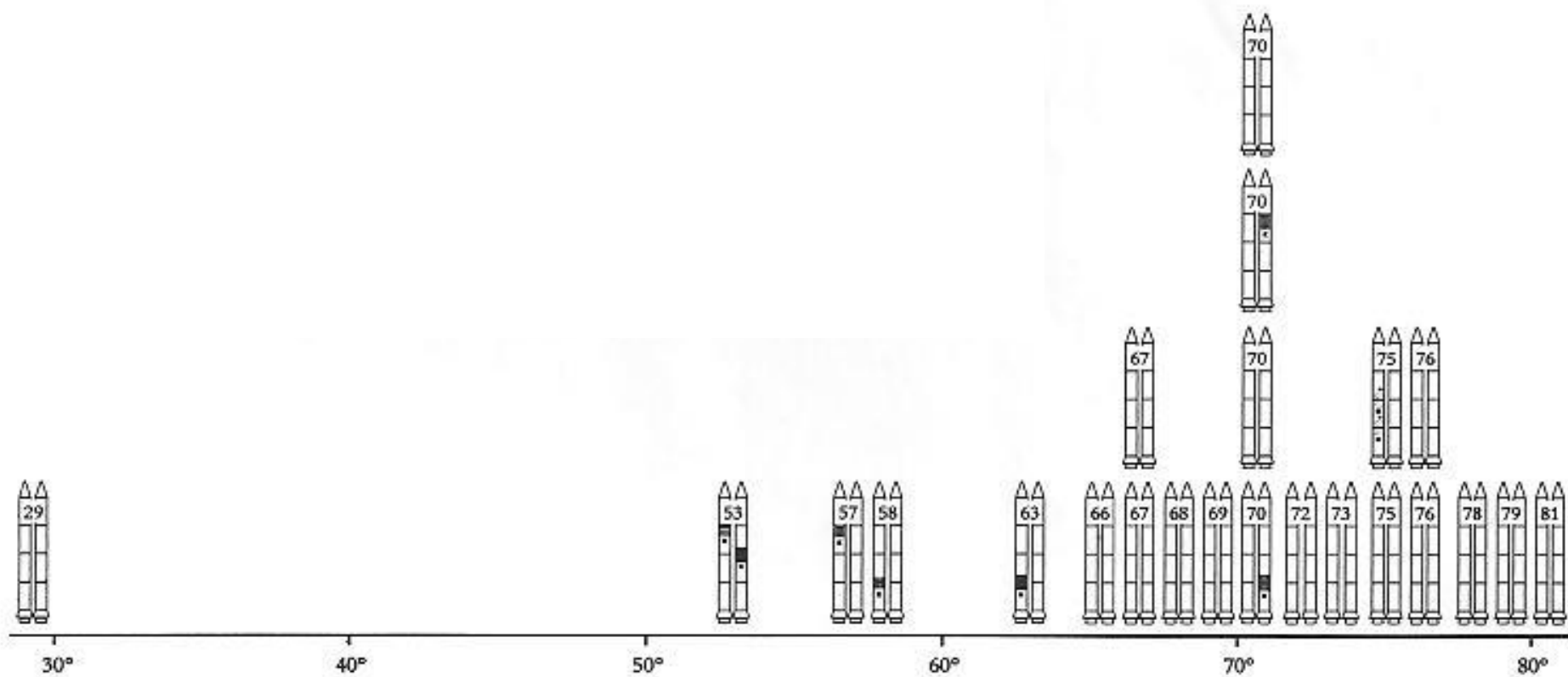
* No Erosion

86486-1E

INFORMATION ON THIS PAGE WAS PREPARED TO SUPPORT AN ORAL PRESENTATION
AND CANNOT BE CONSIDERED COMPLETE WITHOUT THE ORAL DISCUSSION

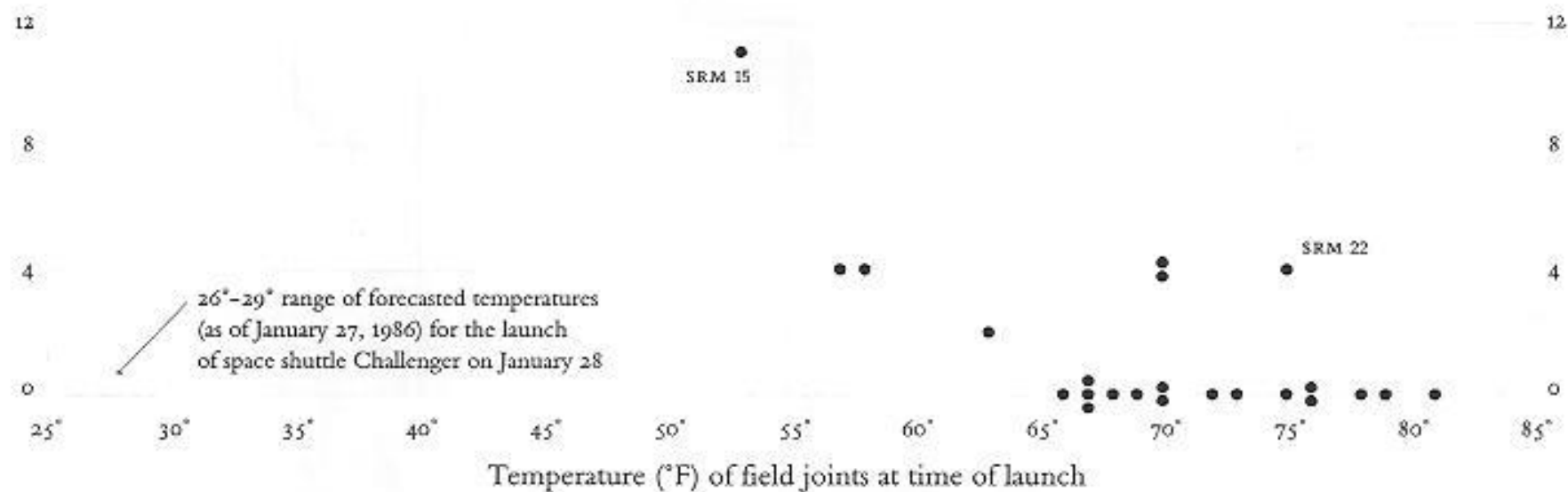
[Ref. 2/26-2 2 of 3]





Flight	Date	Temperature °F	Erosion incidents	Blow-by incidents	Damage index	Comments
51-C	01.24.85	53°	3	2	11	Most erosion any flight; blow-by; back-up rings heated.
41-B	02.03.84	57°	1		4	Deep, extensive erosion.
61-C	01.12.86	58°	1		4	O-ring erosion on launch two weeks before Challenger.
41-C	04.06.84	63°	1		2	O-rings showed signs of heating, but no damage.
1	04.12.81	66°			0	Cooler (66°) launch without O-ring problems.
6	04.04.83	67°			0	
51-A	11.08.84	67°			0	
51-D	04.12.85	67°			0	
5	11.11.82	68°			0	
3	03.22.82	69°			0	
2	11.12.81	70°	1		4	Extent of erosion not fully known.
9	11.28.83	70°			0	
41-D	08.30.84	70°	1		4	
51-G	06.17.85	70°			0	
7	06.18.83	72°			0	
8	08.30.83	73°			0	
51-B	04.29.85	75°			0	
61-A	10.30.85	75°		2	4	No erosion. Soot found behind two primary O-rings.
51-I	08.27.85	76°			0	
61-B	11.26.85	76°			0	
41-G	10.05.84	78°			0	
51-J	10.03.85	79°			0	
4	06.27.82	80°			?	O-ring condition unknown; rocket casing lost at sea.
51-F	07.29.85	81°			0	

O-ring damage
index, each launch



So, communication is
extremely important.

Visualization can help with that –
communicate ideas and insights.



Hans Rosling:

The best stats you've ever seen

TED2006 · 19:50 · Filmed Feb 2006

Subtitles available in 48 languages

https://www.ted.com/talks/hans_rosling_the_best_stats_you_ve_ever_seen

Visualization can also help with
Exploratory Data Analysis (EDA)

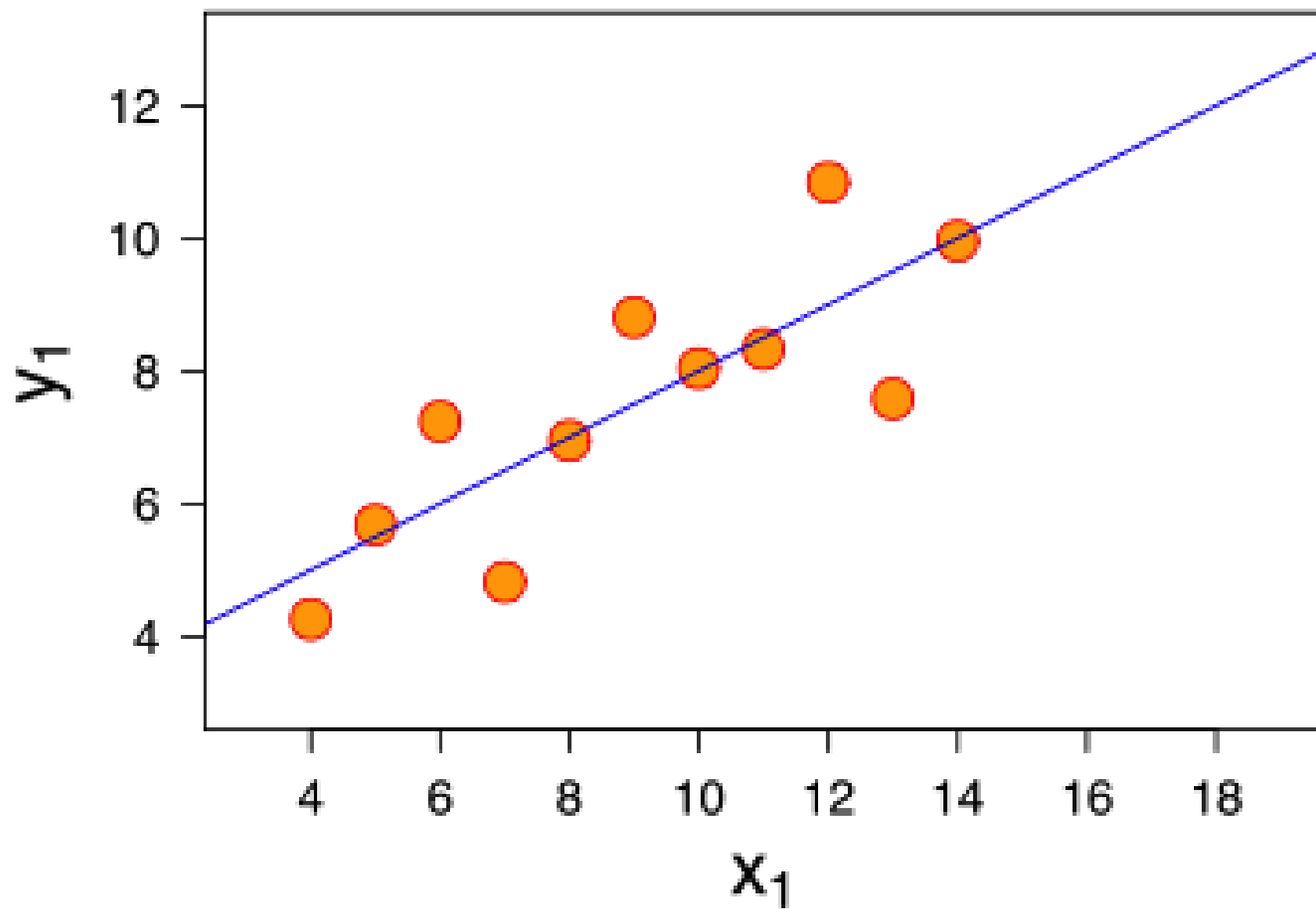
But why do you need to explore
data at all???

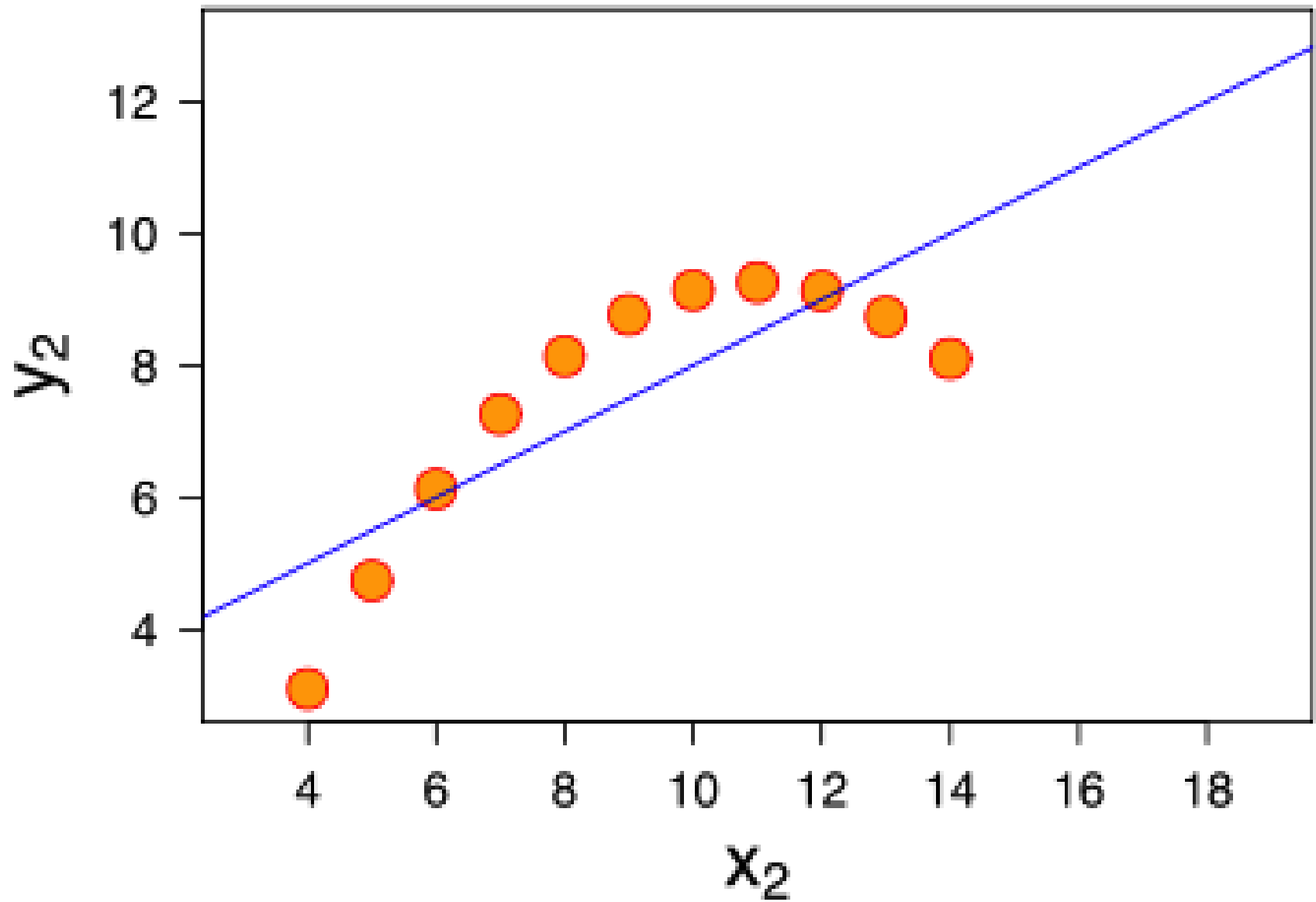
“There are three kinds of lies:
lies, damned lies, and statistics.”

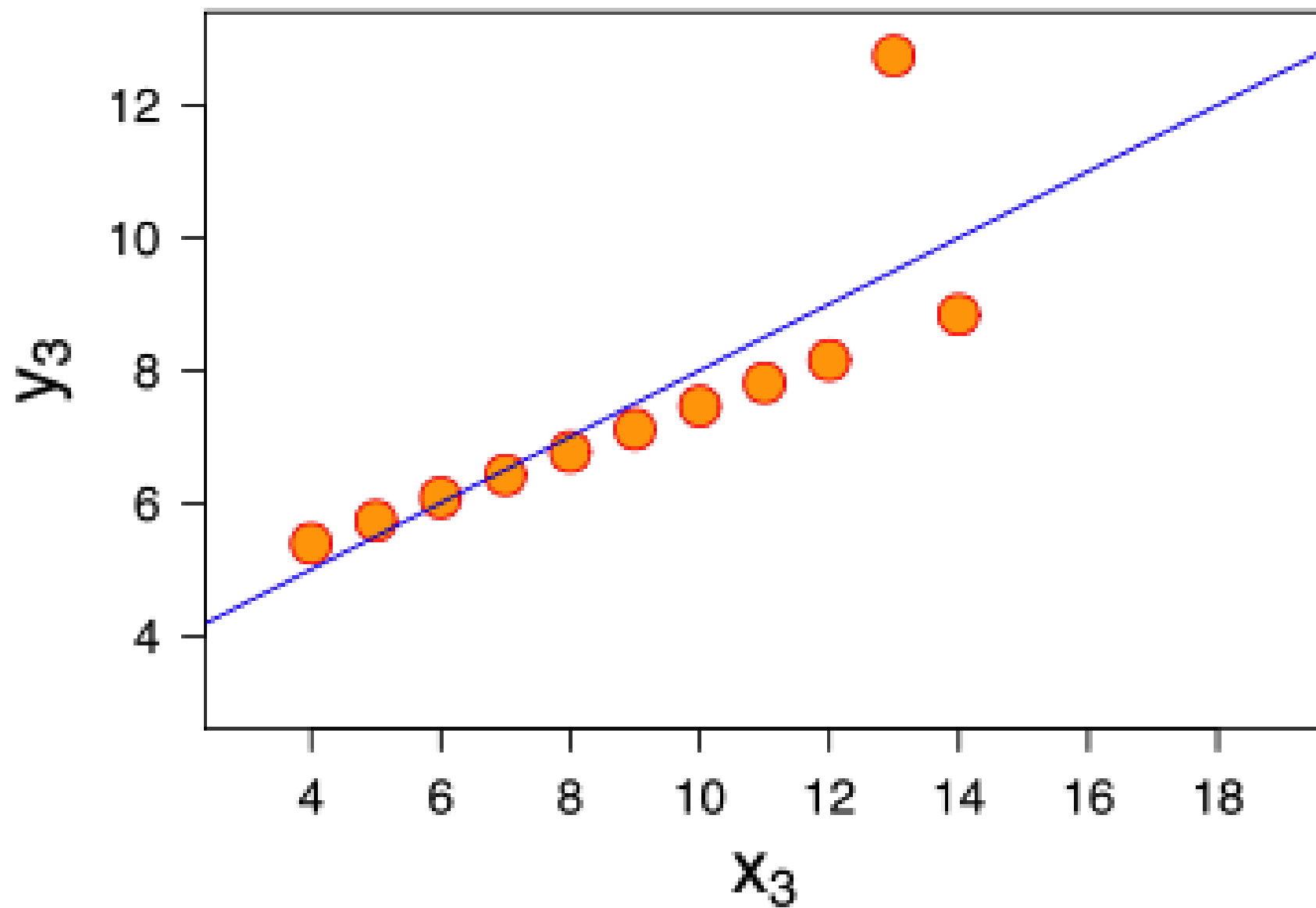
Mystery Data Set

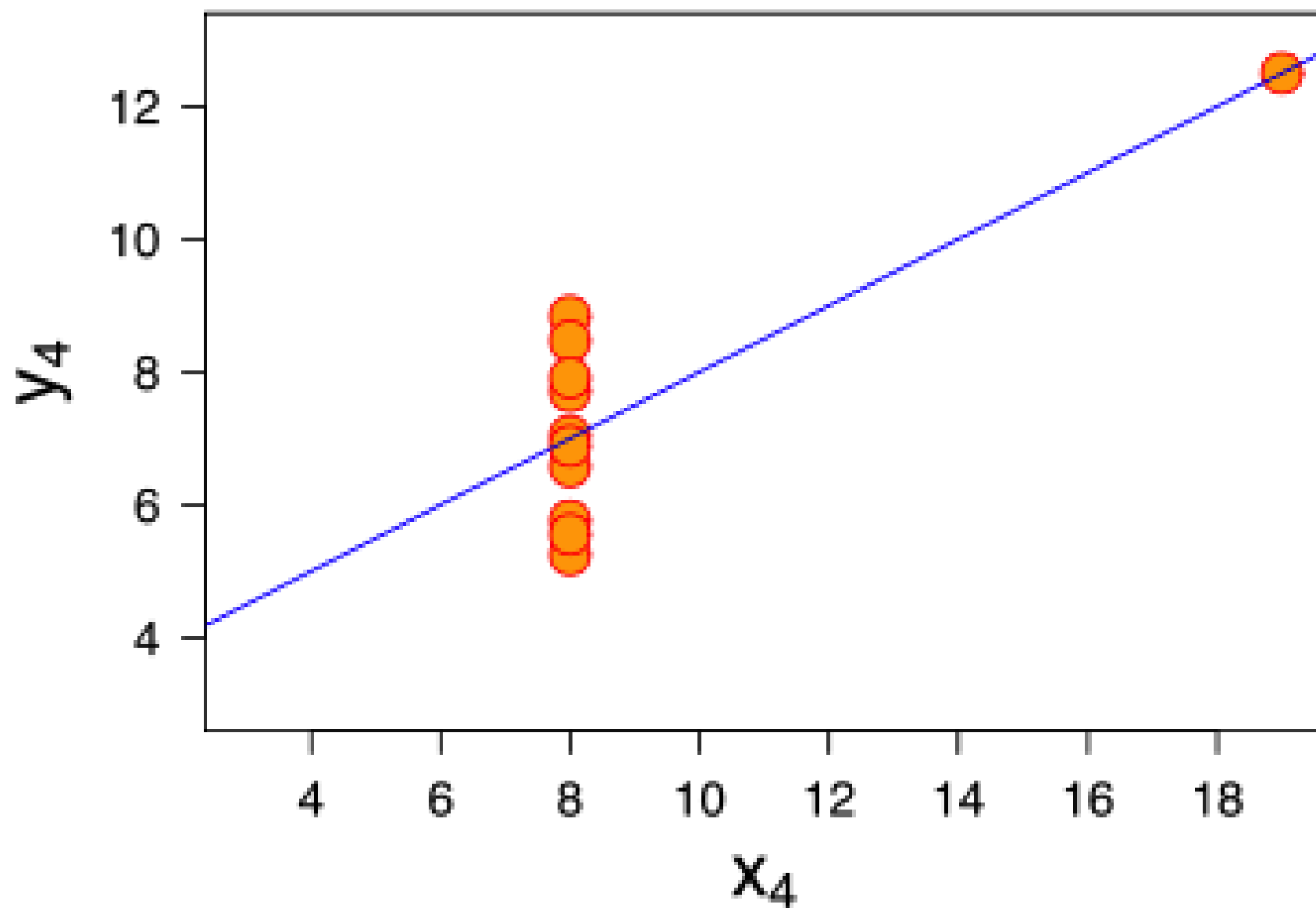
Mystery Data Set

Property	Value
mean(x)	9
variance (x)	11
mean(y)	7.5
variance (y)	4.122
correlation (x,y)	0.816
Linear Regression Line	$y = 3 + 0.5x$

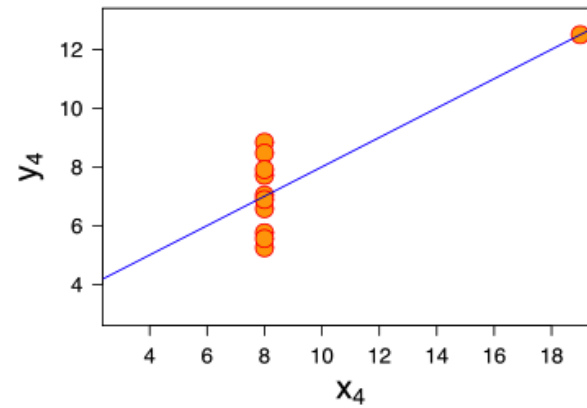
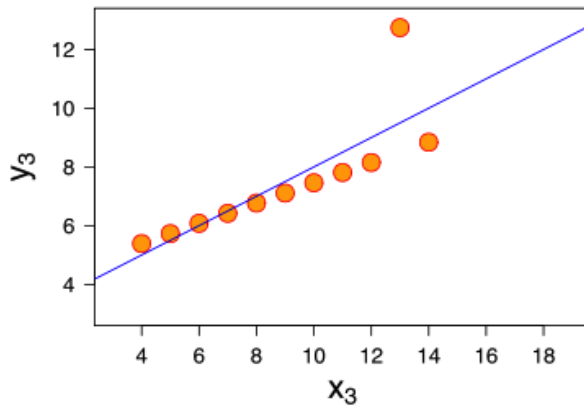
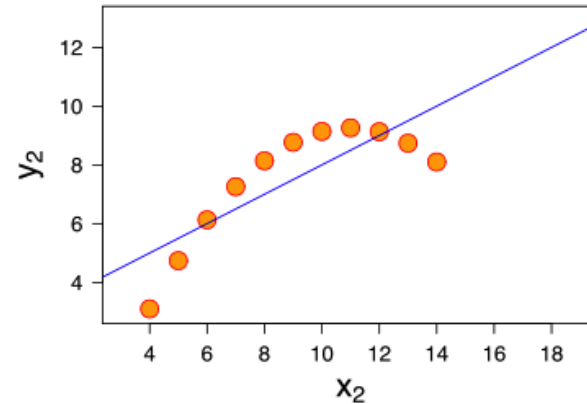
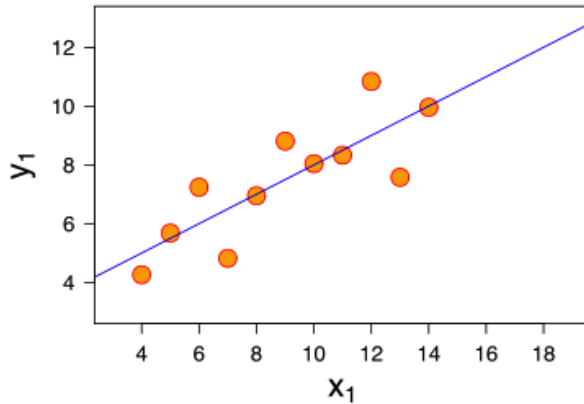






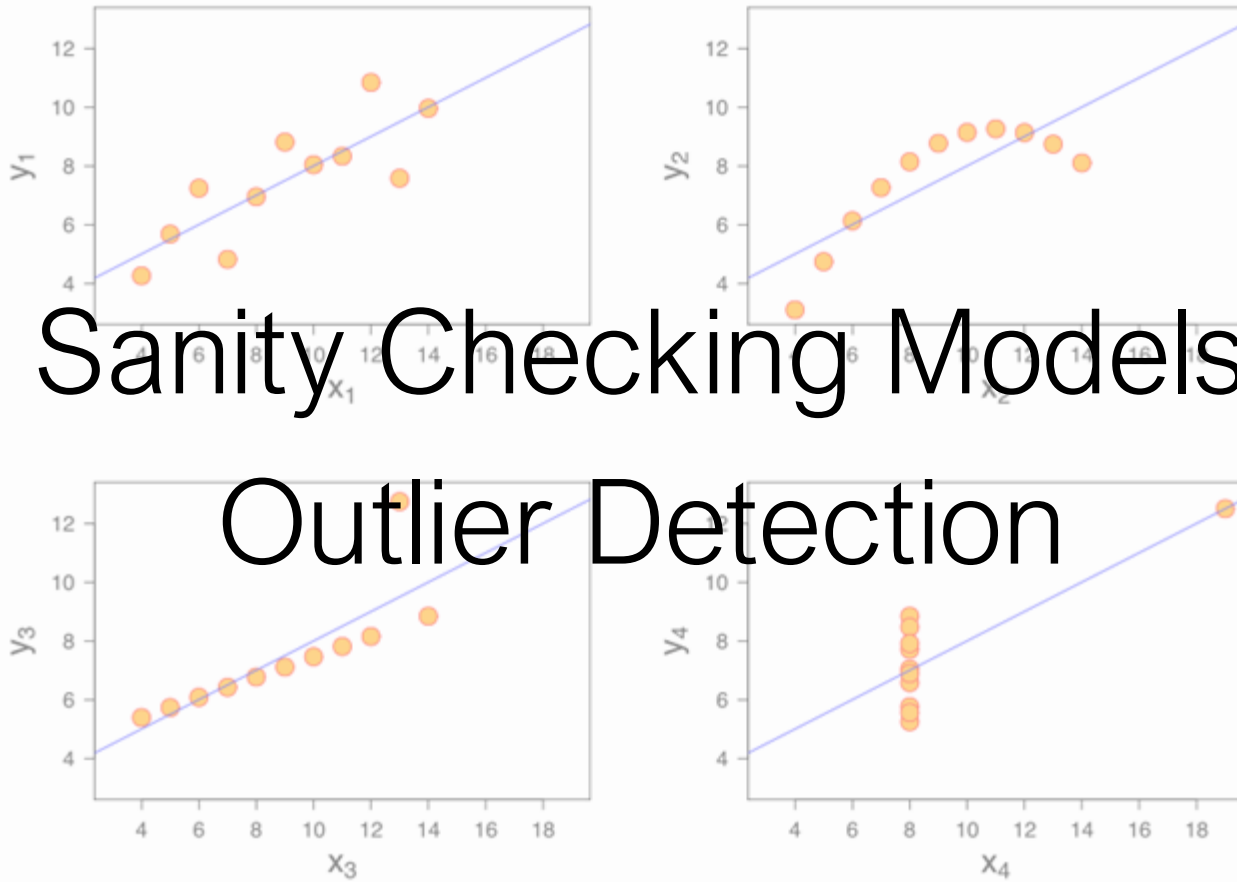


Anscombe's Quartet



https://en.wikipedia.org/wiki/Anscombe%27s_quartet

Anscombe's Quartet



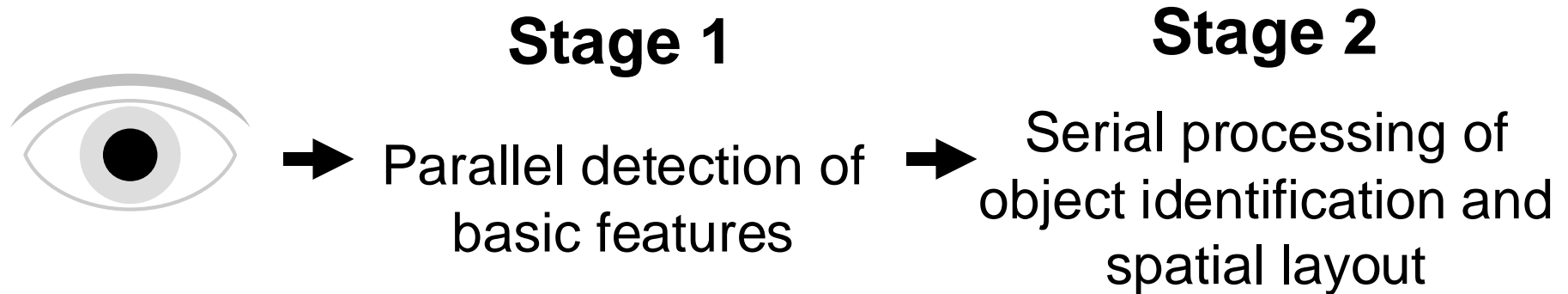
Data visualization leverages
human perception

Name the five senses.

Sense	Bandwidth (bits/sec)
Sight	10,000,000
Touch	1,000,000
Hearing	100,000
Smell	100,000
Taste	1,000

A (Simple) Model of Human Visual Perception

A (Simple) Model of Human Perception



Stage 1: Pre-Attentive Processing

Rapid
Parallel
Automatic

(Fleeting = lasting for a short time)

Stage 2: Serial Processing

Relatively Slow
(Incorporates Memory)
Manual

Stage 1: Pre-Attentive Processing

The eye moves every 200ms
(so this processing occurs every
200ms-250ms)

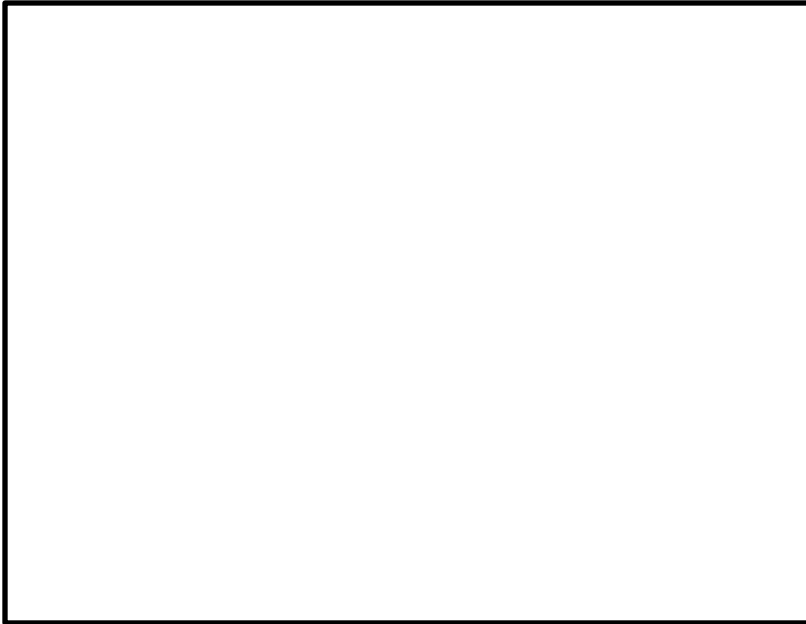
Example

1281768756138976546984506985604982826762
9809858458224509856458945098450980943585
9091030209905959595772564675050678904567
8845789809821677654876364908560912949686

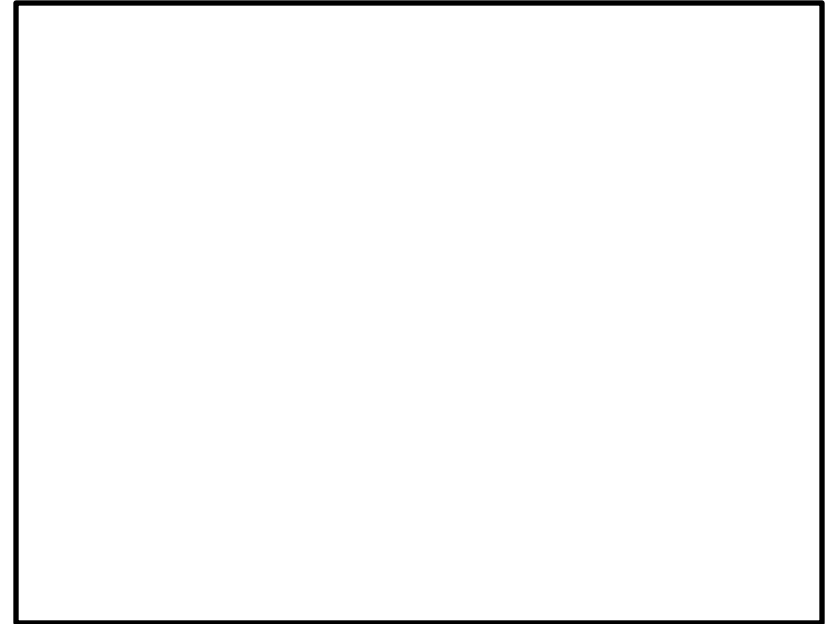
Example

1281768756138976546984506985604982826762
9809858458224509856458945098450980943585
9091030209905959595772564675050678904567
8845789809821677654876364908560912949686

A few more examples from
Prof. Chris Healy at NC State



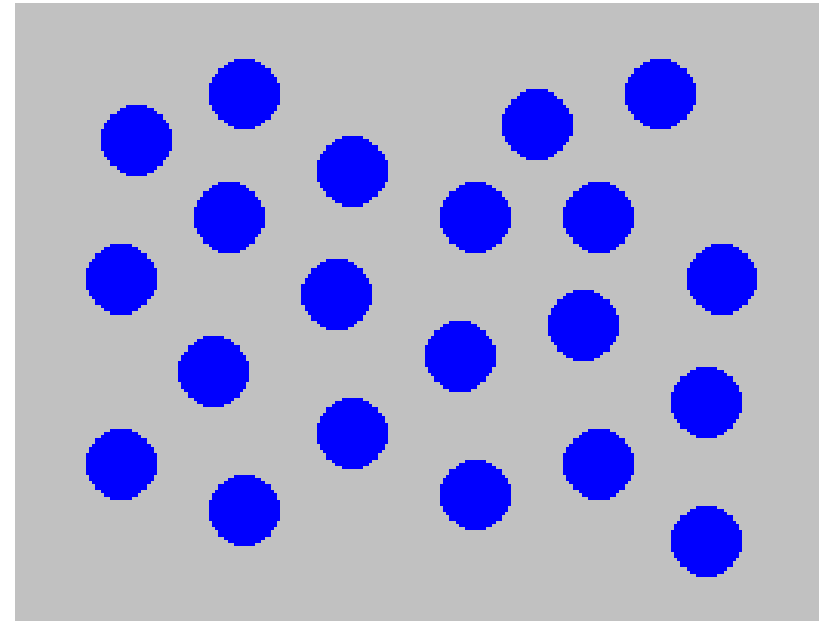
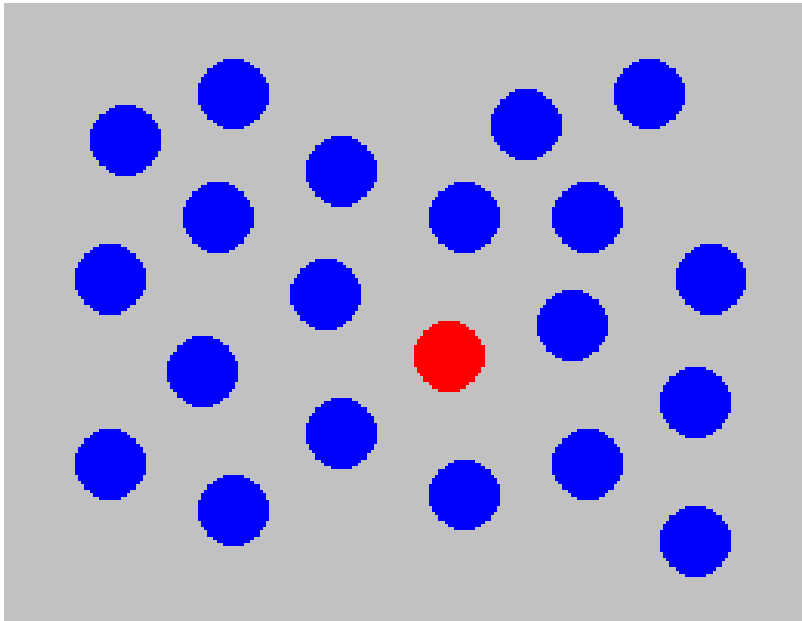
Left Side



Right Side

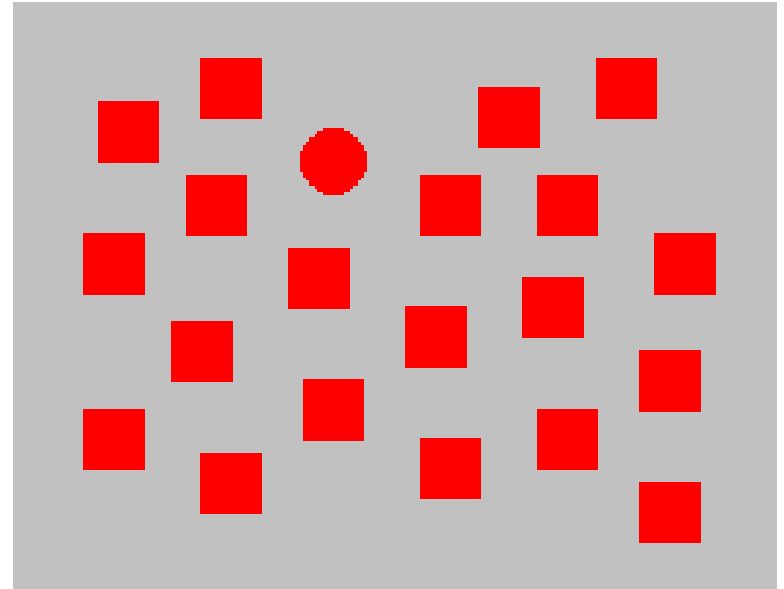
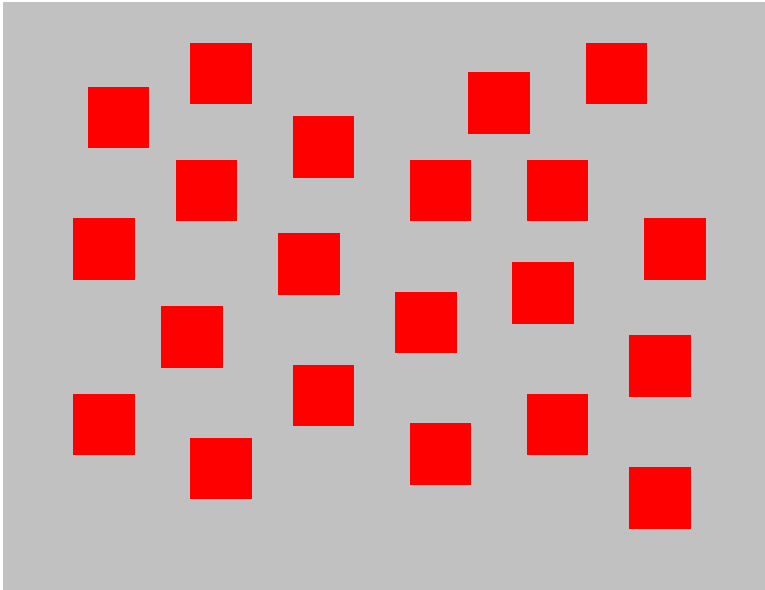
Raise your hand if a **RED DOT**
is present...

(On the left or on the right?)



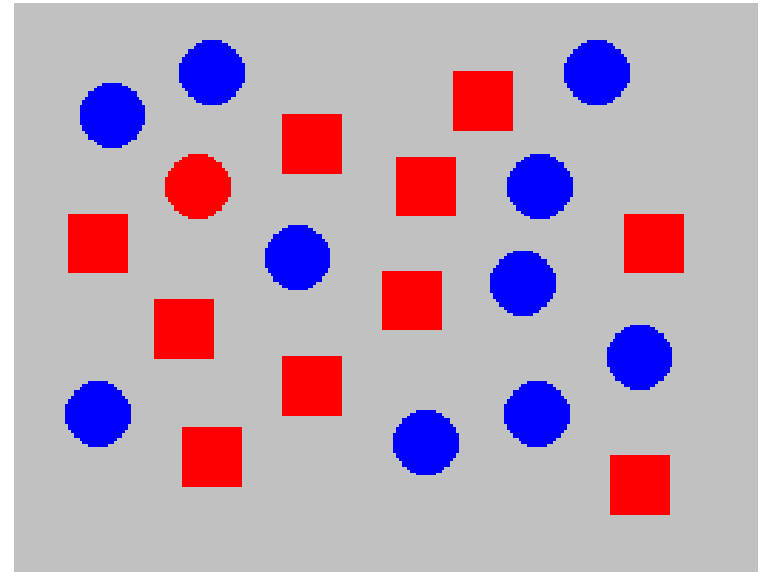
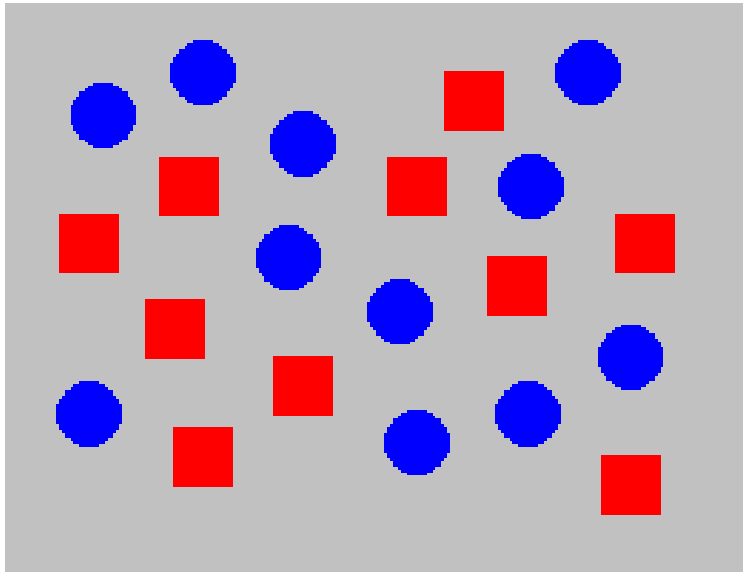
Color (hue) is pre-attentively processed.

Raise your hand if a RED DOT
is present...



Shape is pre-attentively
processed.

Determine if a RED DOT is
present...



Hue and shape together are
NOT pre-attentively processed.

Pre-Attentive Processing

- length
- width
- size
- curvature
- number
- terminators
- intersection
- closure
- hue
- lightness
- flicker
- direction of motion
- binocular lustre
- stereoscopic depth
- 3-D depth cues
- lighting direction

Group	Attribute		
Form	Length	Width	Orientation
	Size	Shape	Curvature
	Enclosure	Blur	
Color	Hue	Intensity	
Spatial Position	2-D Position	Spatial Grouping	
Motion	Direction		

Stephen F

“Now You

pg. 39

Stephen Few
 “Now You See It”
 pg. 39

Pre-Attentive → Cognitive

Gestalt Psychology

Berlin, Early 1900s

Gestalt Psychology

Goal was to understand
pattern perception

Gestalt (German) = “seeing the whole picture all at once”
instead of a collection of parts

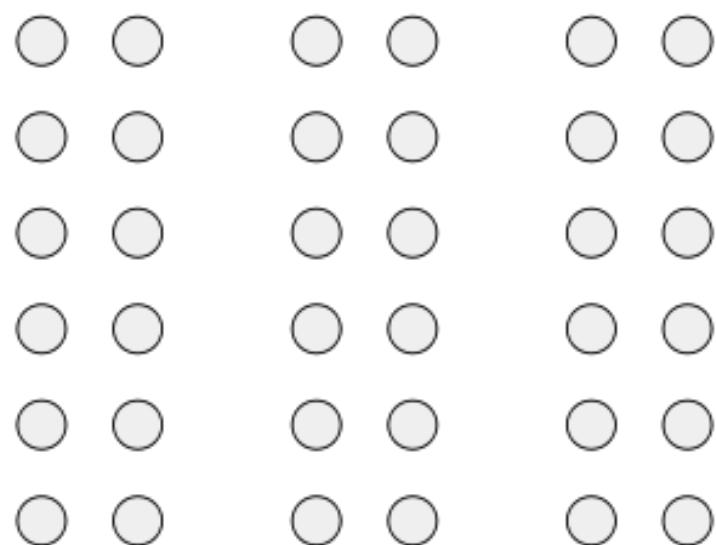
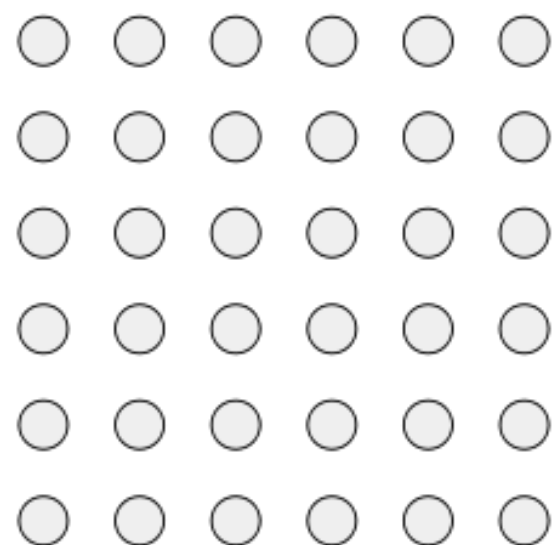
Identified 8 “Laws of Grouping”

<http://study.com/academy/lesson/gestalt-psychology-definition-principles-quiz.html>

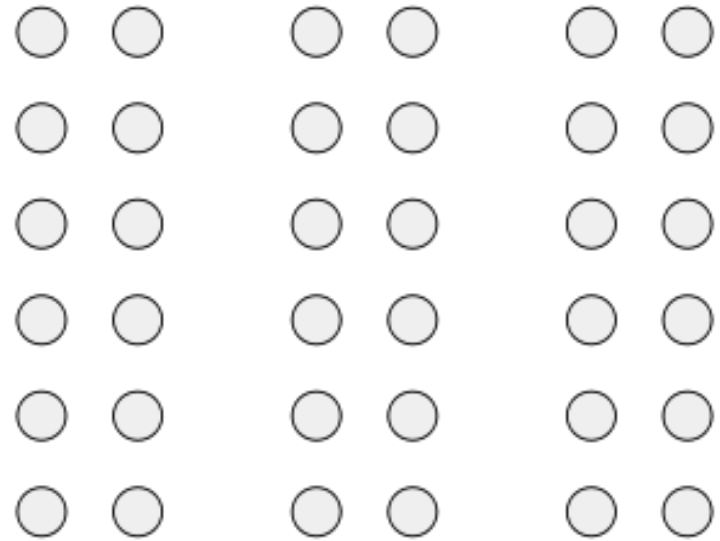
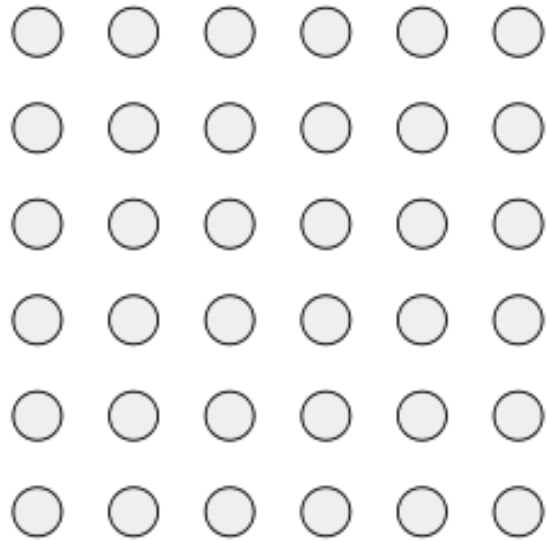
Gestalt Psychology

1. Proximity
2. Similarity
3. Closure
4. Symmetry
5. Common Fate
6. Continuity
7. Good Gestalt
8. Past Experience

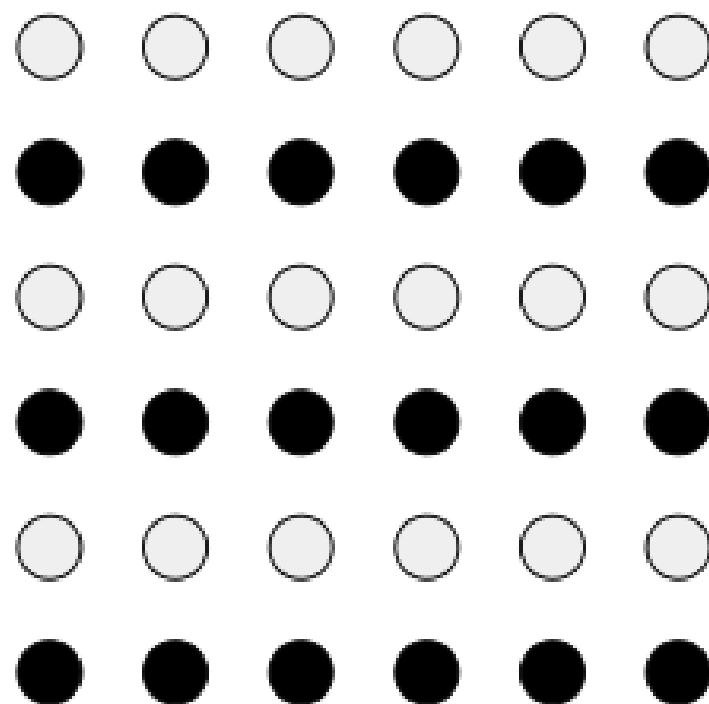
How many groups are there?



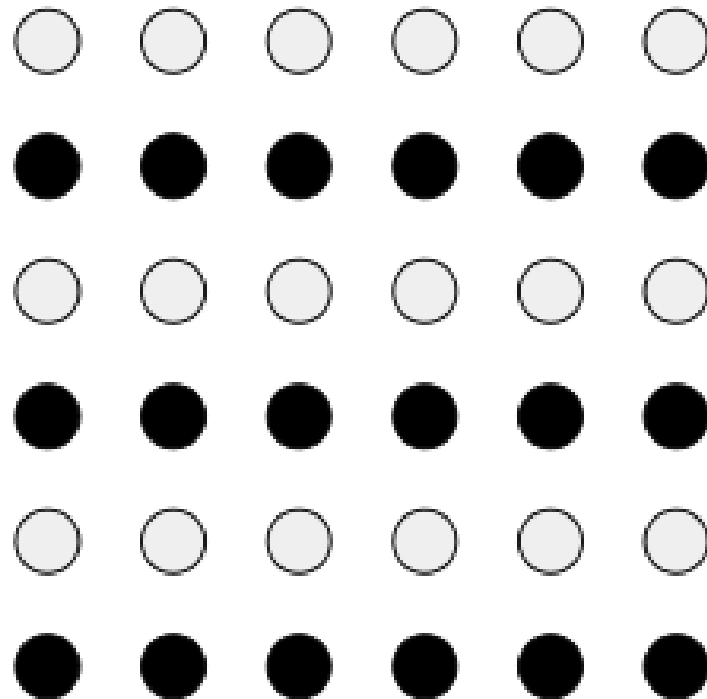
Proximity



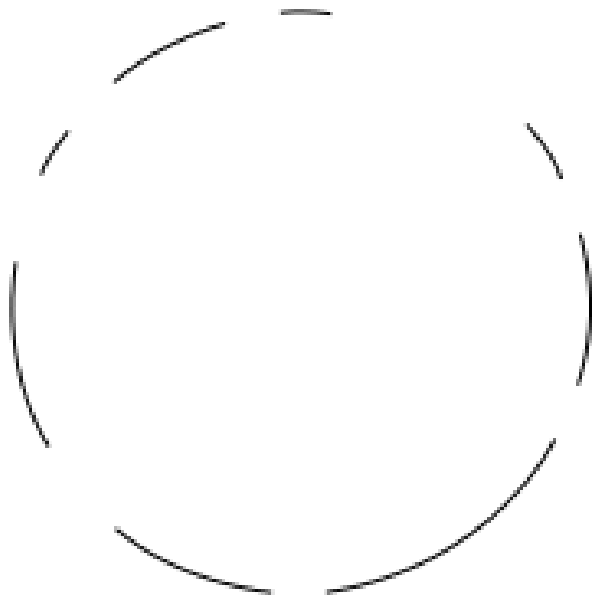
How many groups are there?



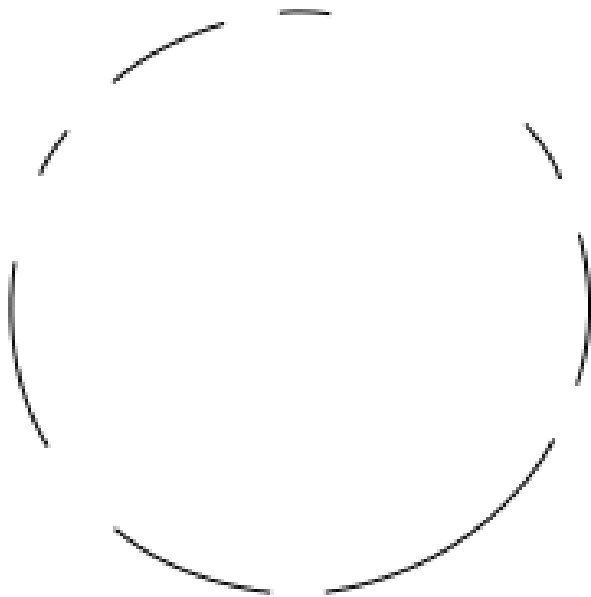
Similarity



How many shapes are there?



Closure



How many items are there?

()

{ }

[]

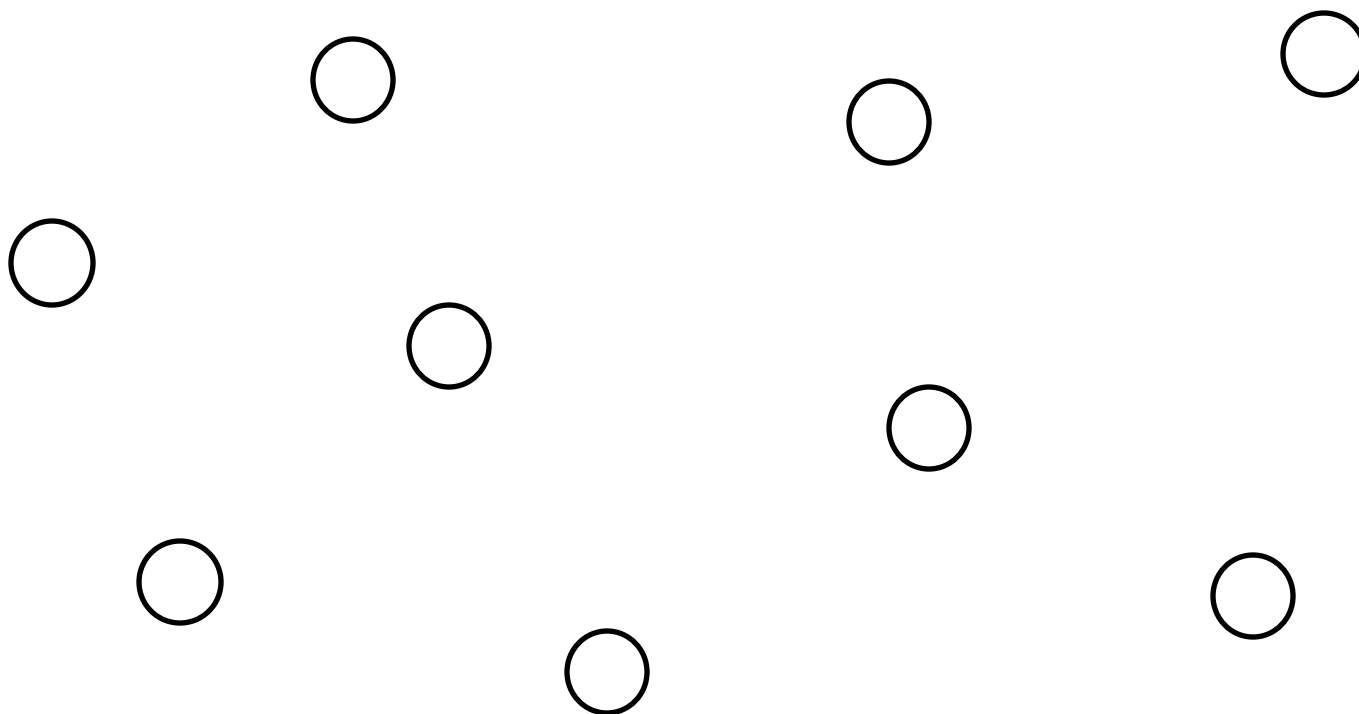
Symmetry

()

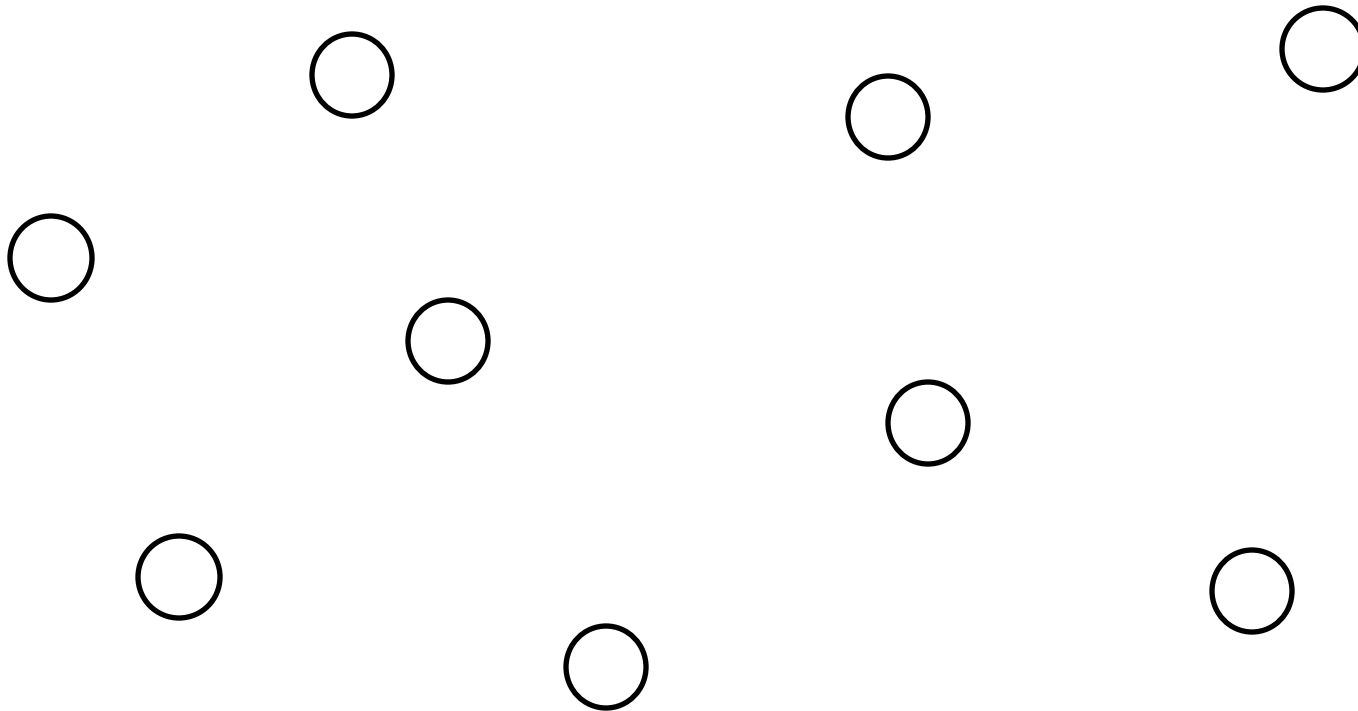
{ }

[]

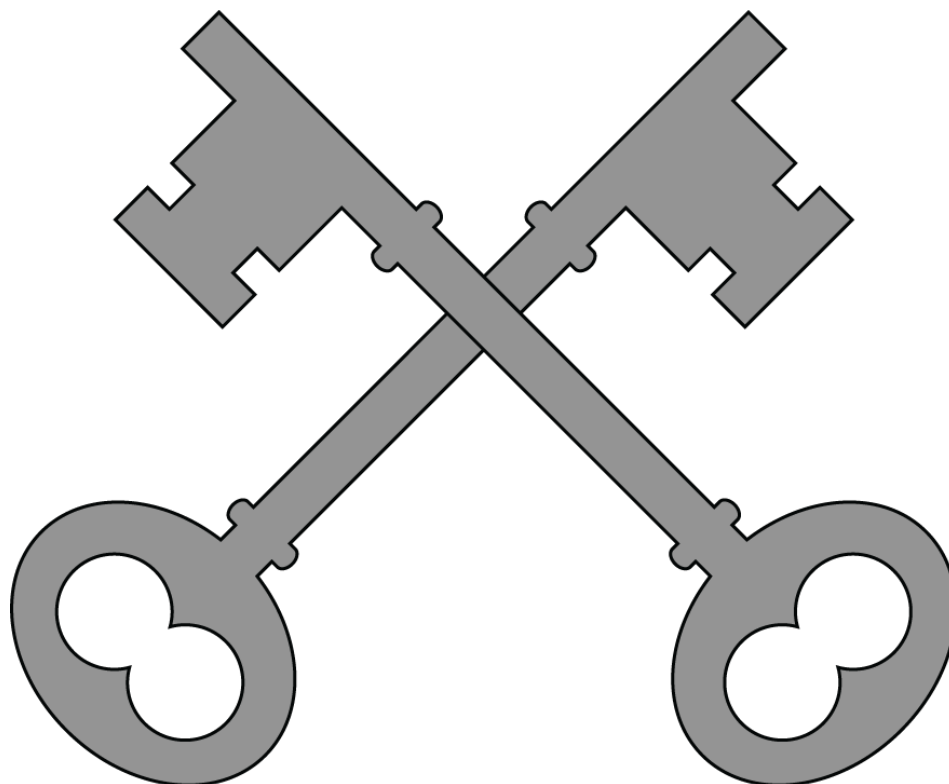
How many sets are there?



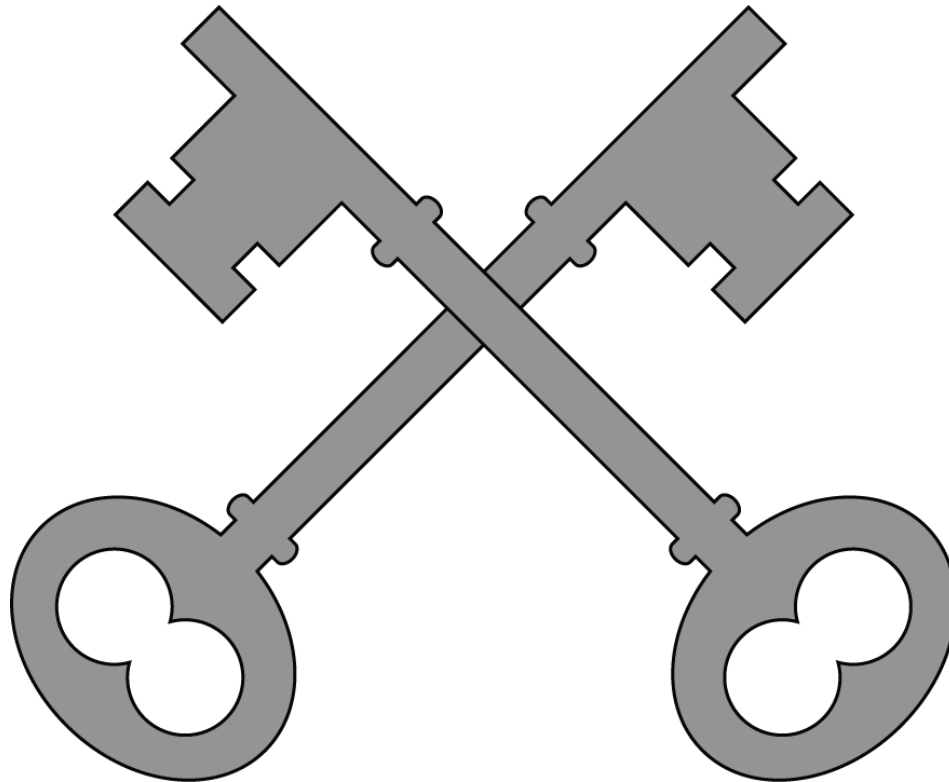
Common Fate



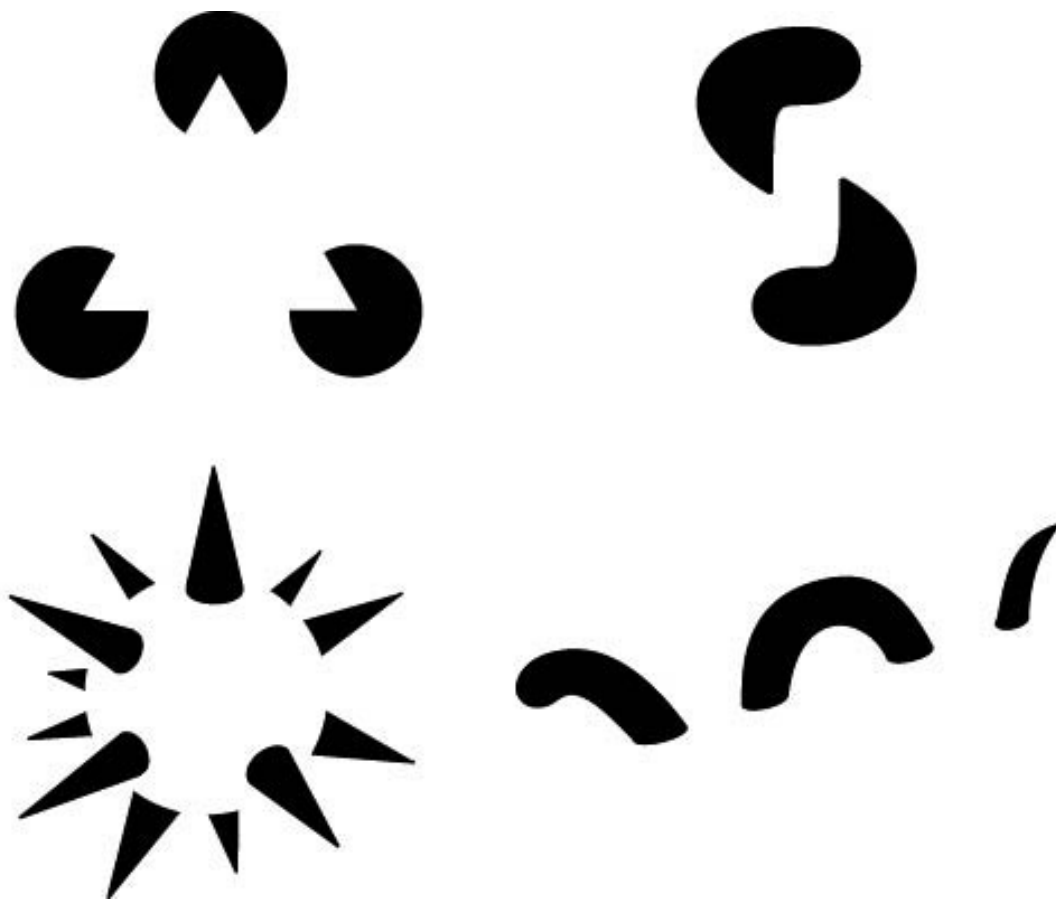
How many objects are there?



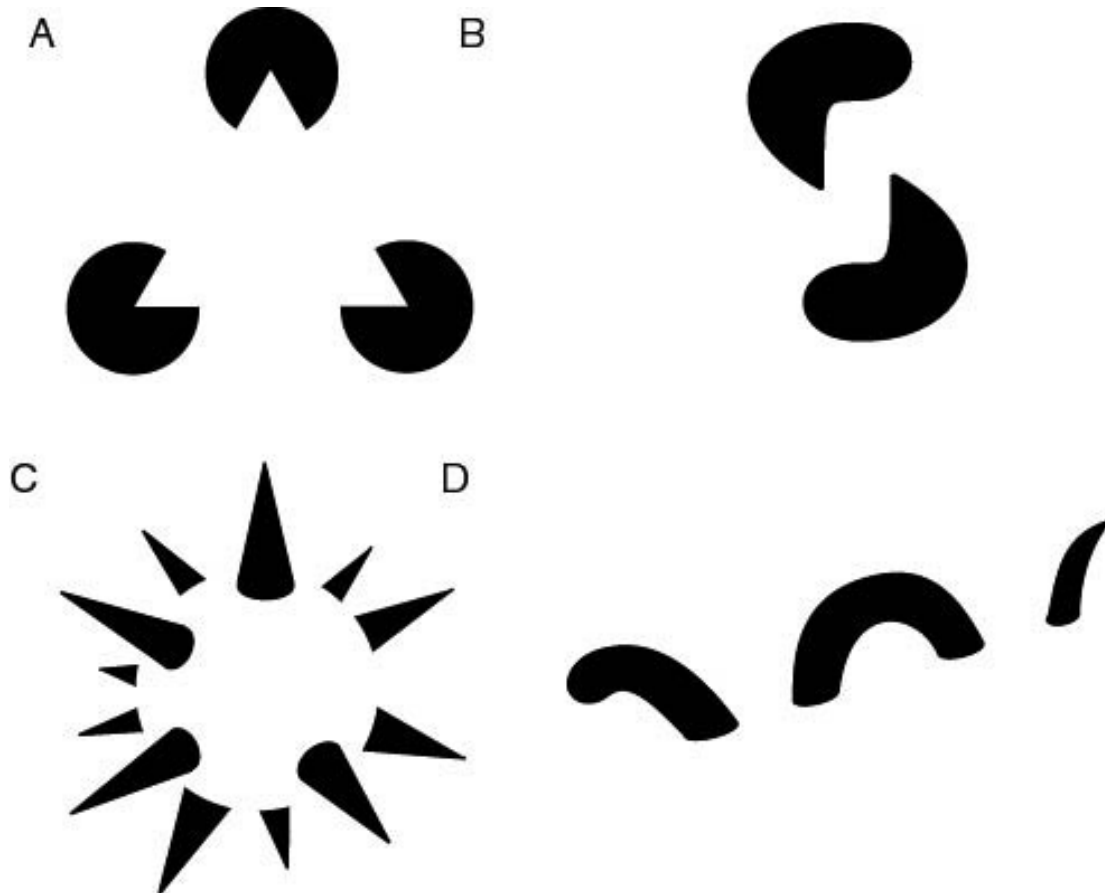
Continuity



How many objects are there?



Good Gestalt



What is this word?

FLIGHT

Past Experience

FLIGHT

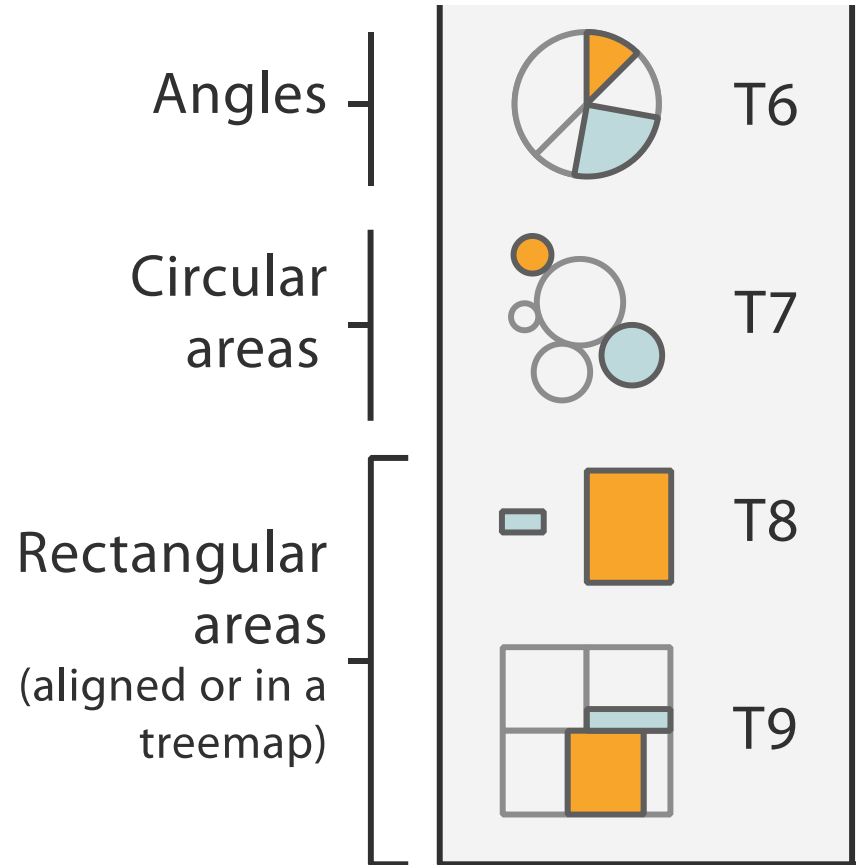
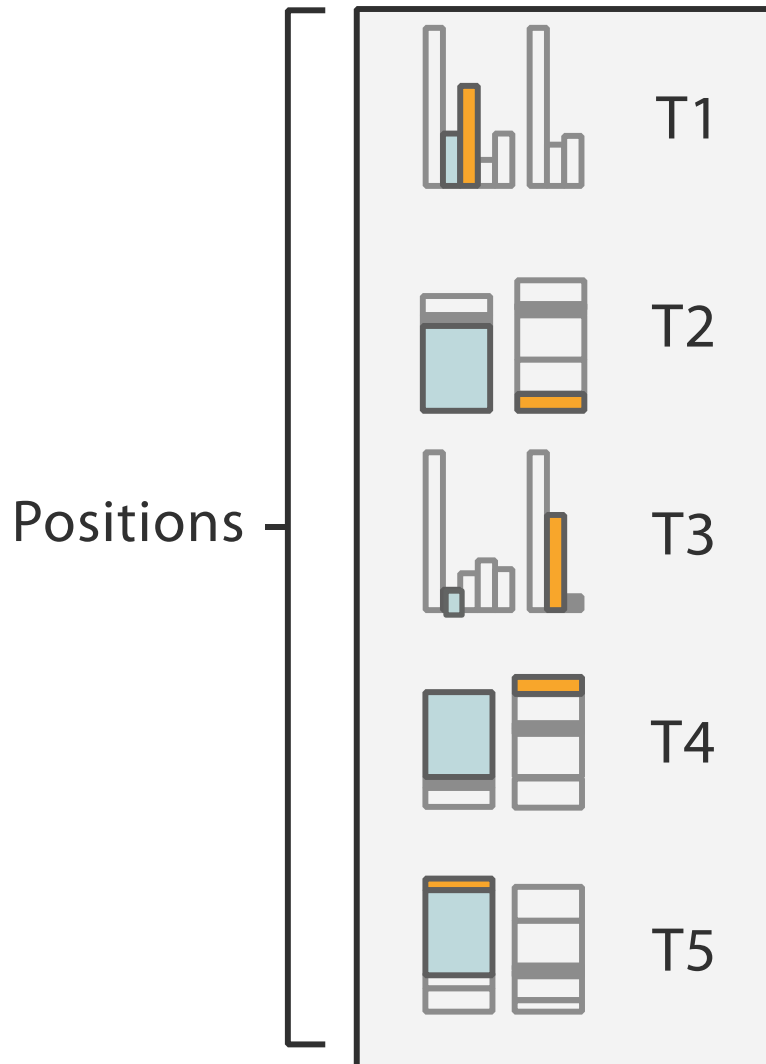
Pre-Attentive Processing

Gestalt Laws

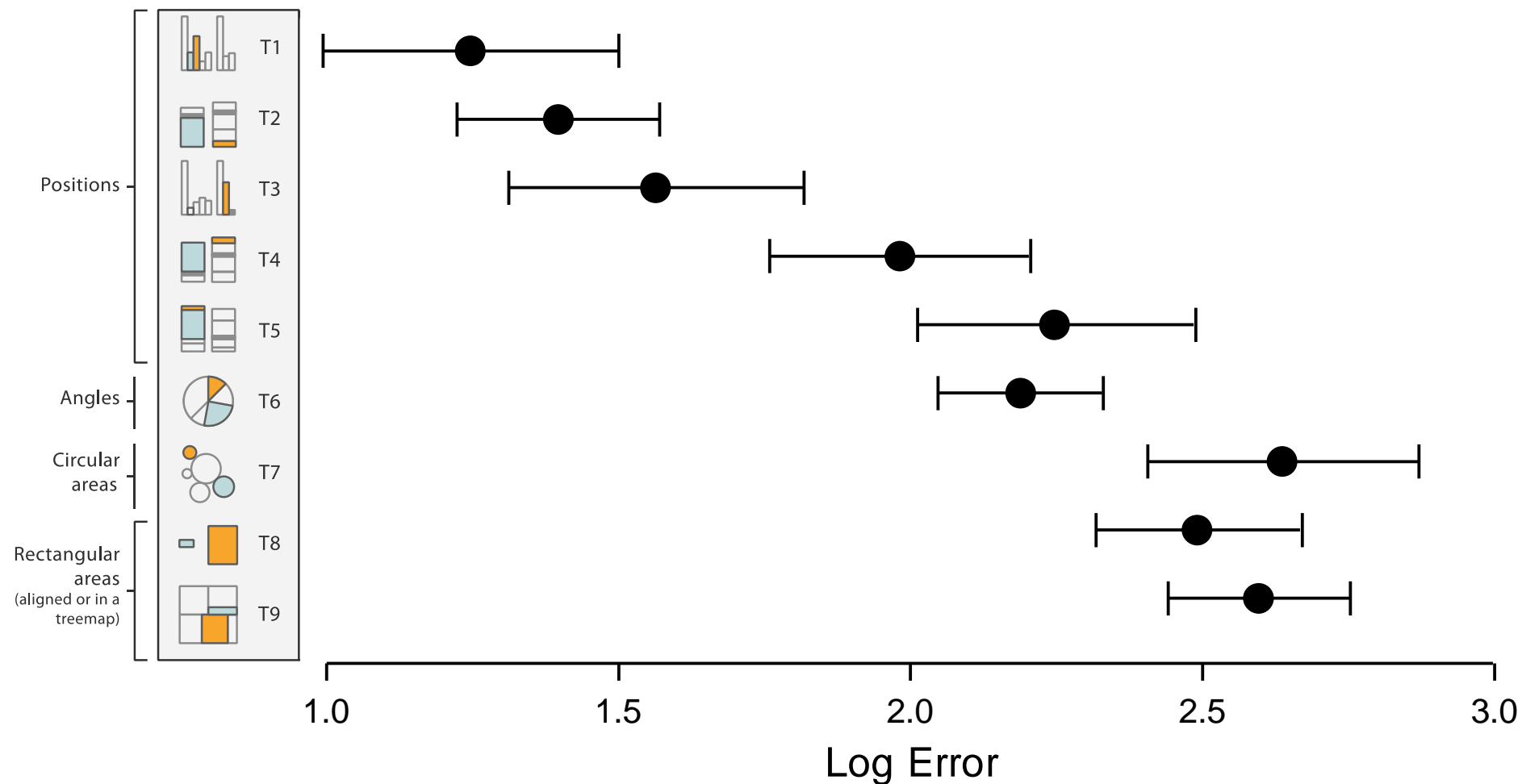
Detect Quickly

Detect quickly **does NOT** mean
detect accurately

Ideally you want both.



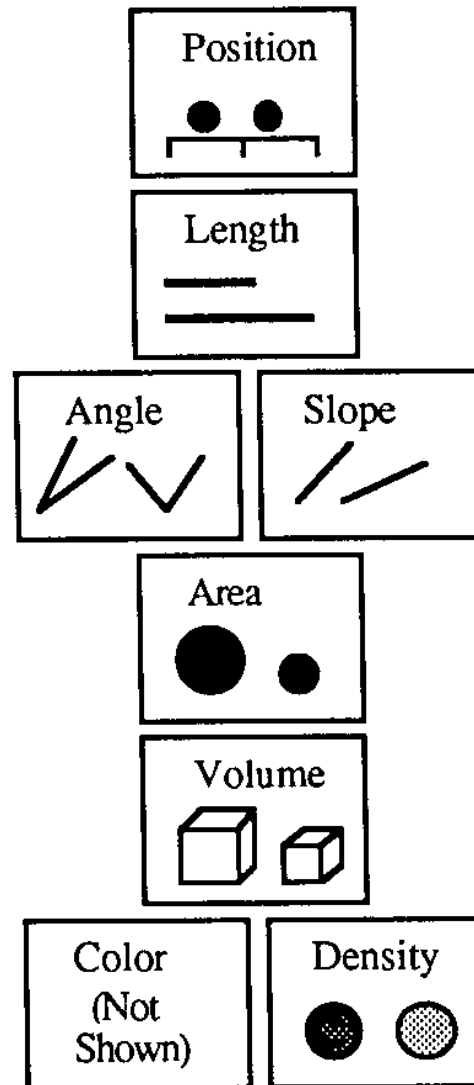
Crowdsourced Results



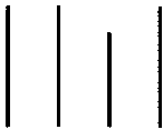
More accurate



Less accurate

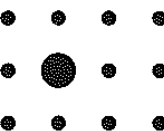


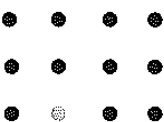
Precision of Quantitative Perception	Attribute	Example	Description
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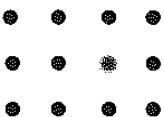
Very precise	Length		Longer = greater
--------------	--------	--	------------------

	2-D Position		Higher or farther to the right = greater
--	--------------	--	--

Not very precise	Width		Wider = greater
------------------	-------	--	-----------------

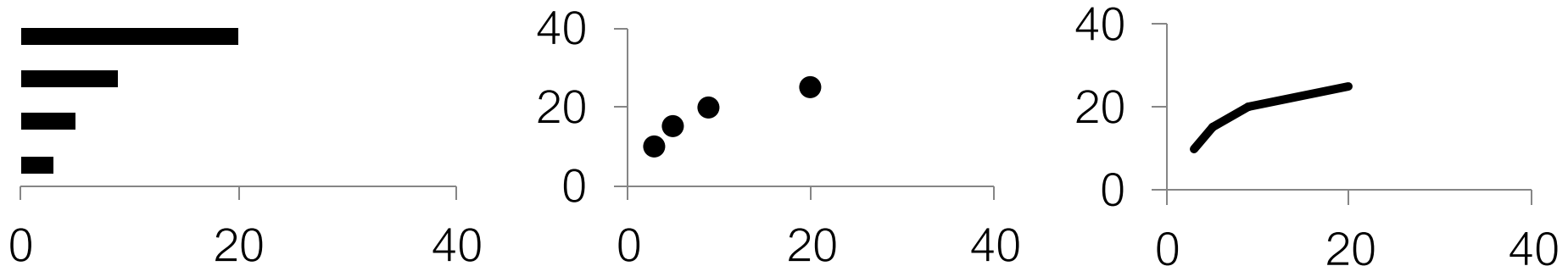
	Size		Bigger = greater
--	------	--	------------------

	Intensity		Darker = greater
--	-----------	---	------------------

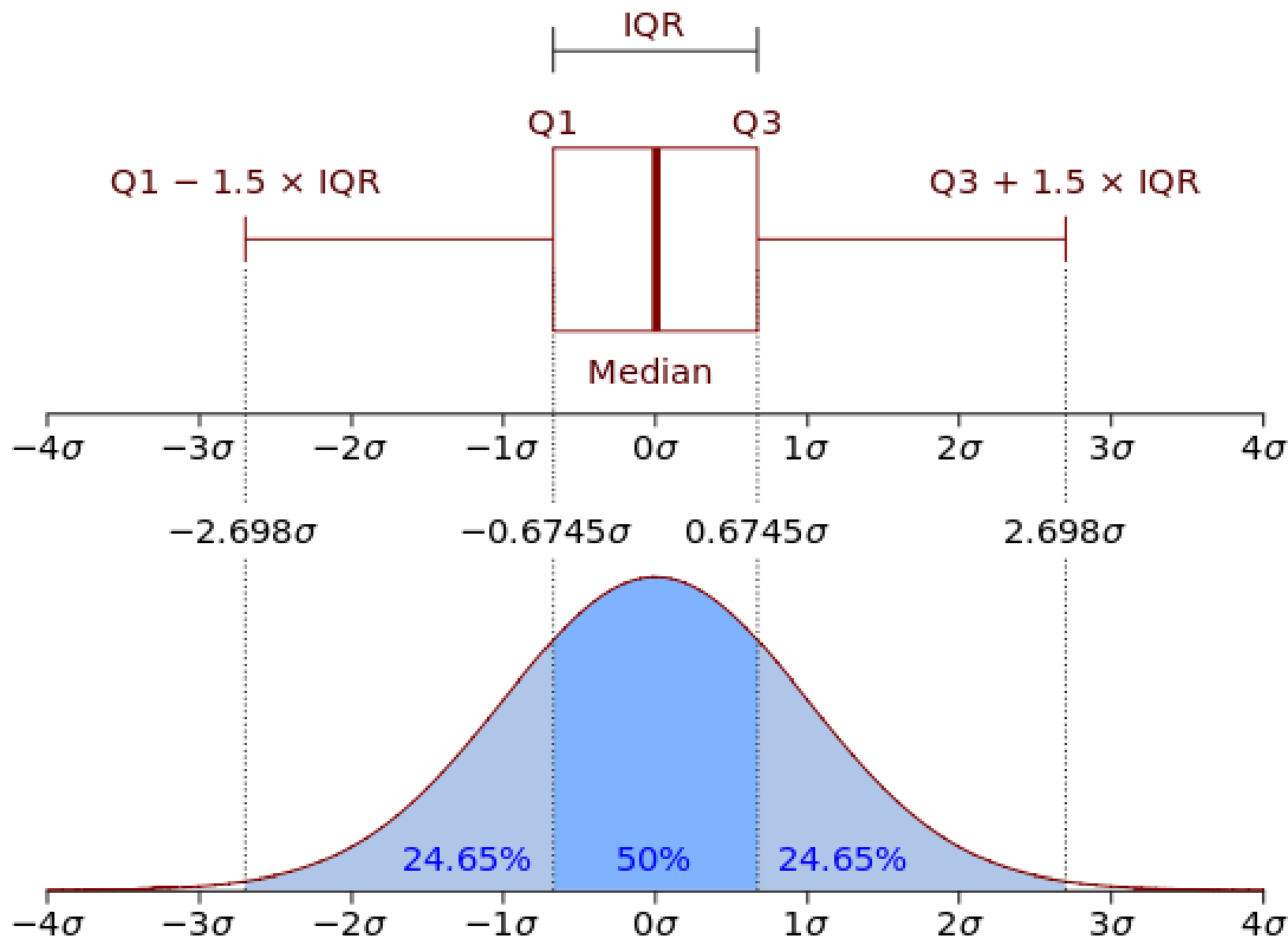
	Blur		Clearer = greater
--	------	--	-------------------

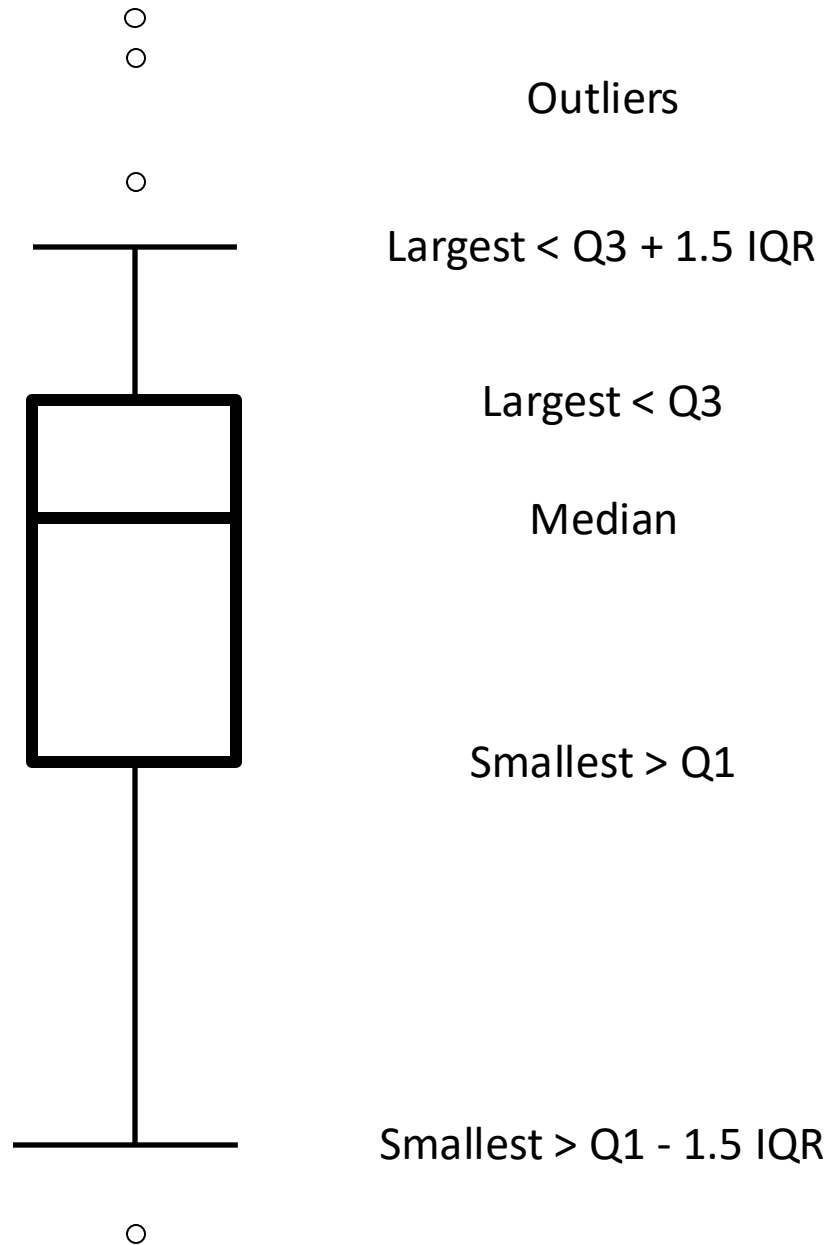
What does this tell us?

Bar charts, scatterplots, and line charts are *really* effective for quantitative data



(and for statistical distributions)
Tukey Box Plots





Tufte's Chart Principles



Edward Tufte

Tufte's Chart Principles

DO NOT LIE!

Tufte's Chart Principles

DO NOT LIE!

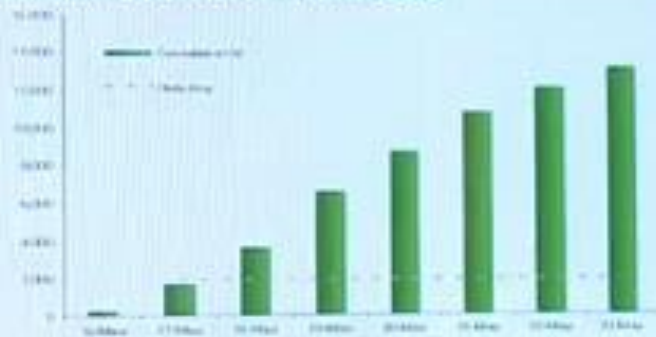
Maximize Data-Ink Ratio

Minimize Chart Junk

Subsea Oil Collection

- Avg circa 2,000 bbl per day
- Total of 13,500 bbls collected

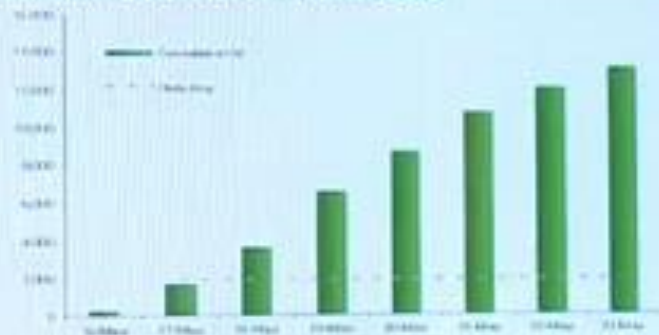
Cumulative Oil Collected, bbls



Flow Injection Tube Tool (FITT)

“Cumulative”

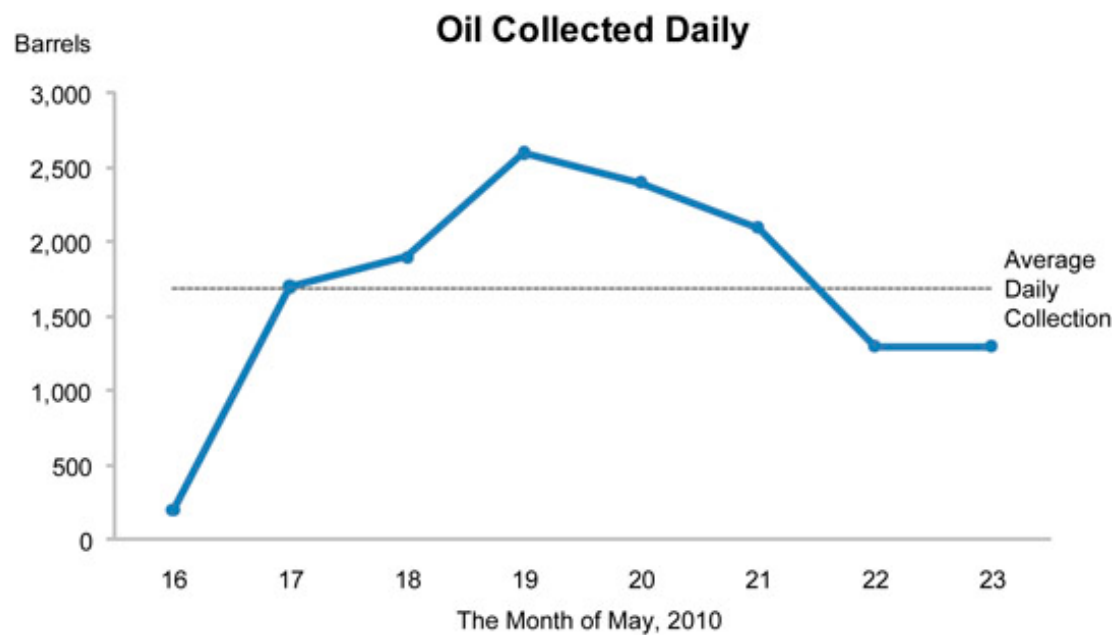
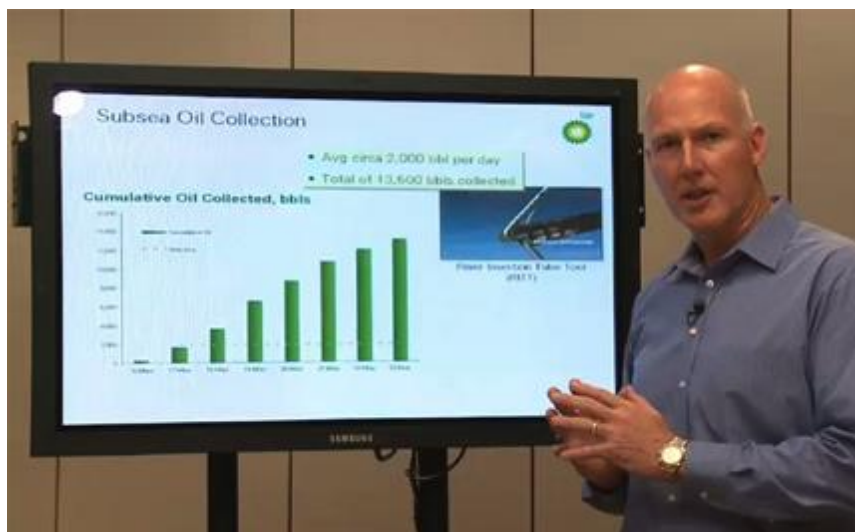
Cumulative Oil Collected, bbls



- Avg circa 2,000 bbl per day
- Total of 13,500 bbls collected



Three Injection Tube Tool (TITT)

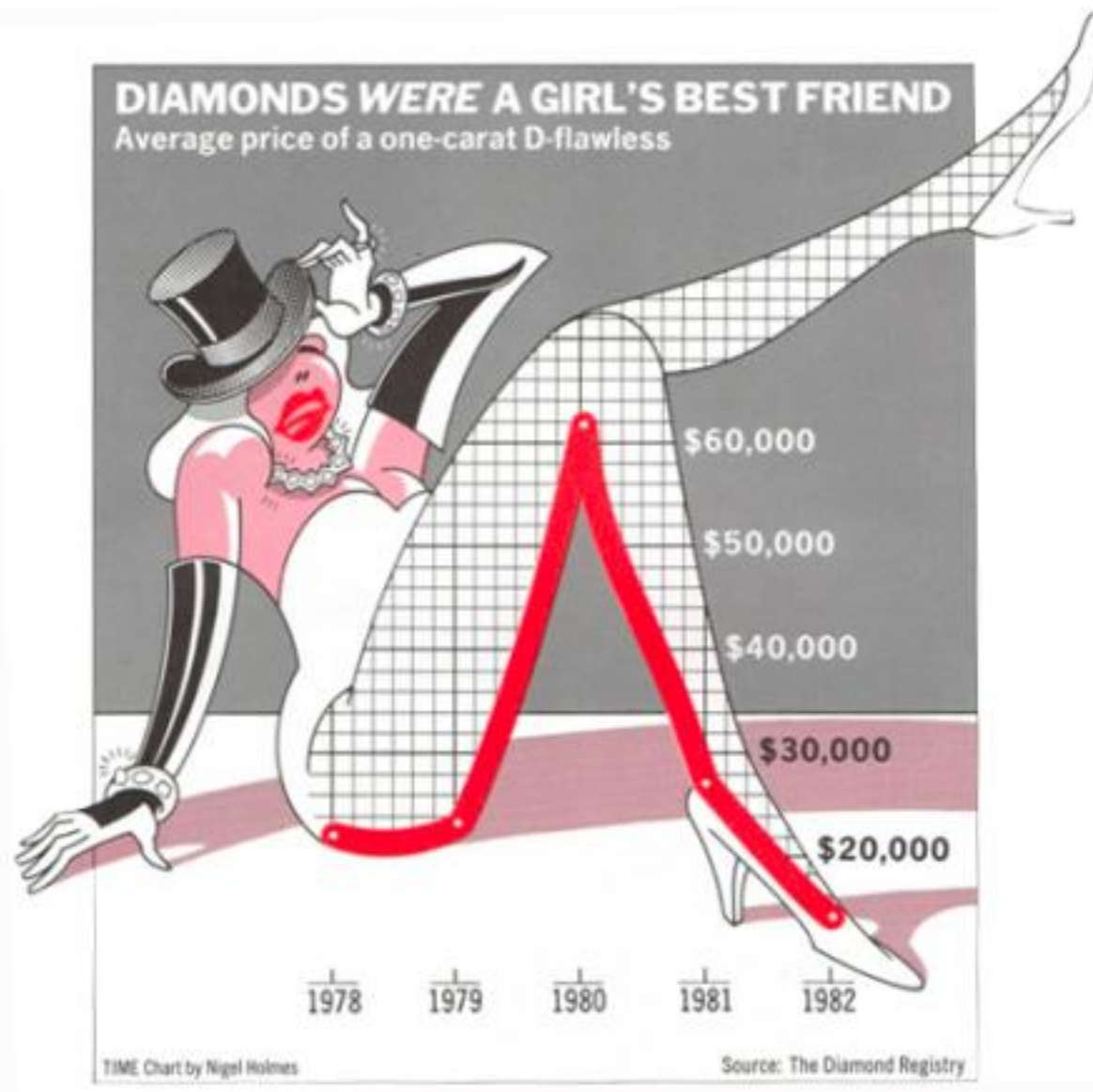


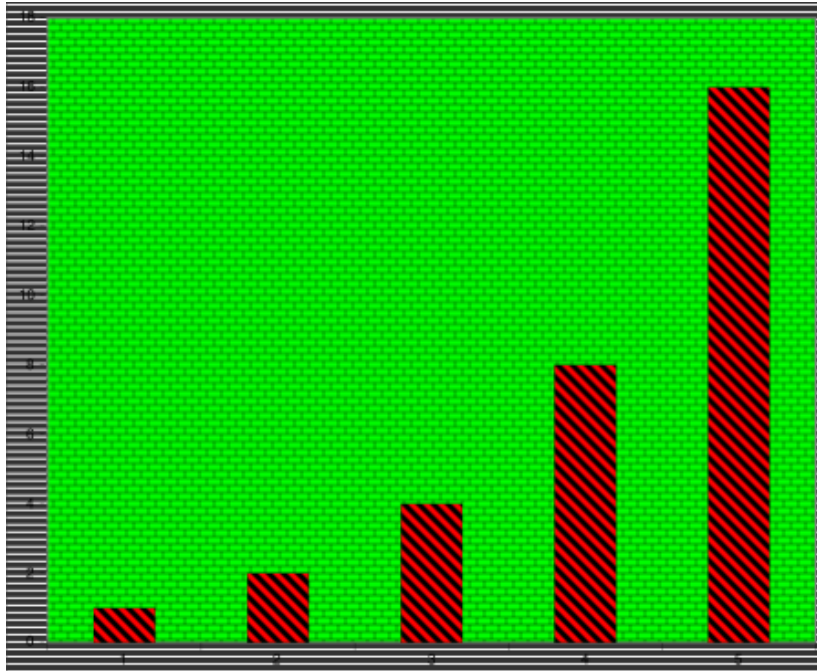
Tufte's Chart Principles

DO NOT LIE!

Maximize Data-Ink Ratio

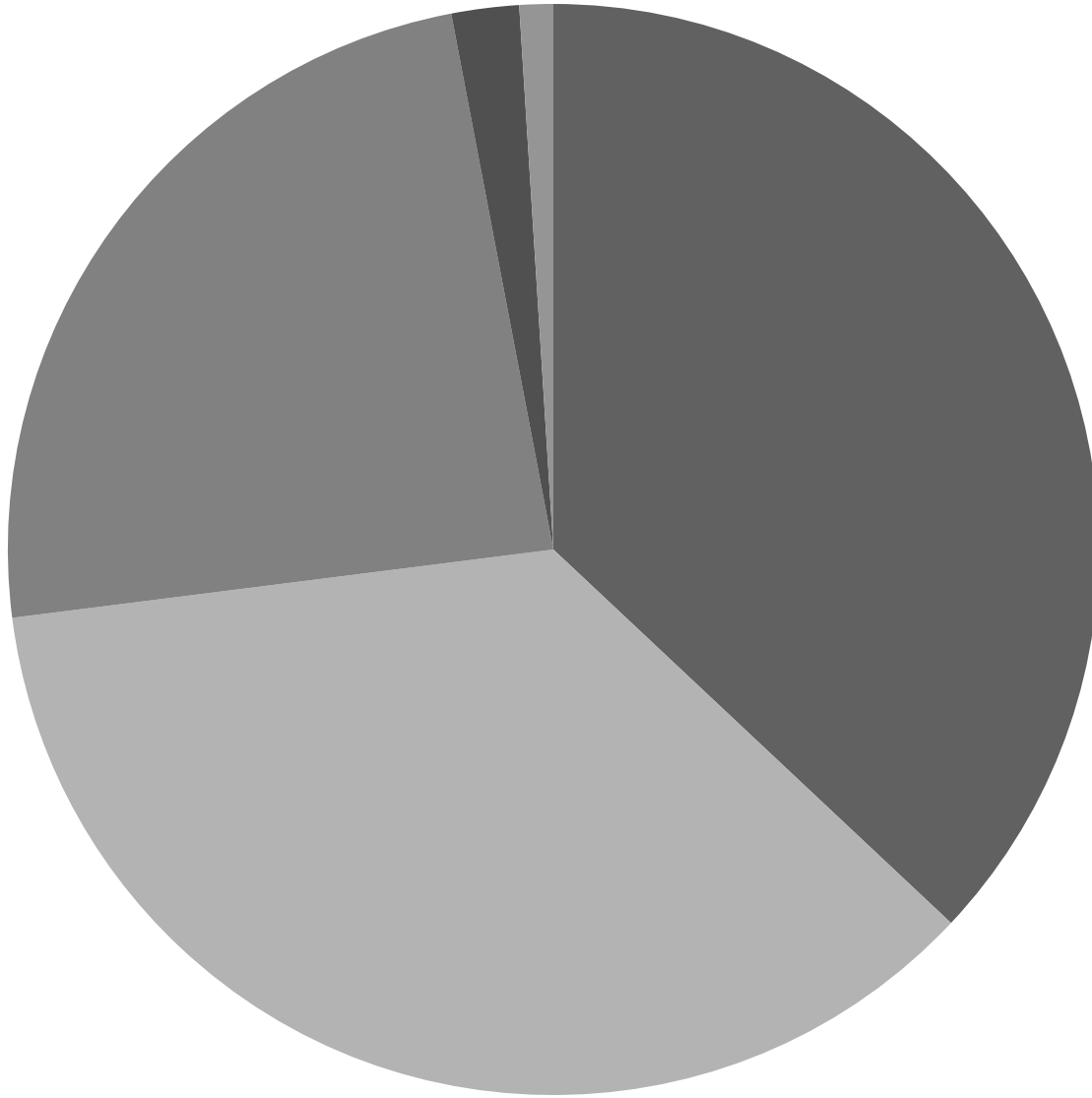
Minimize Chart Junk

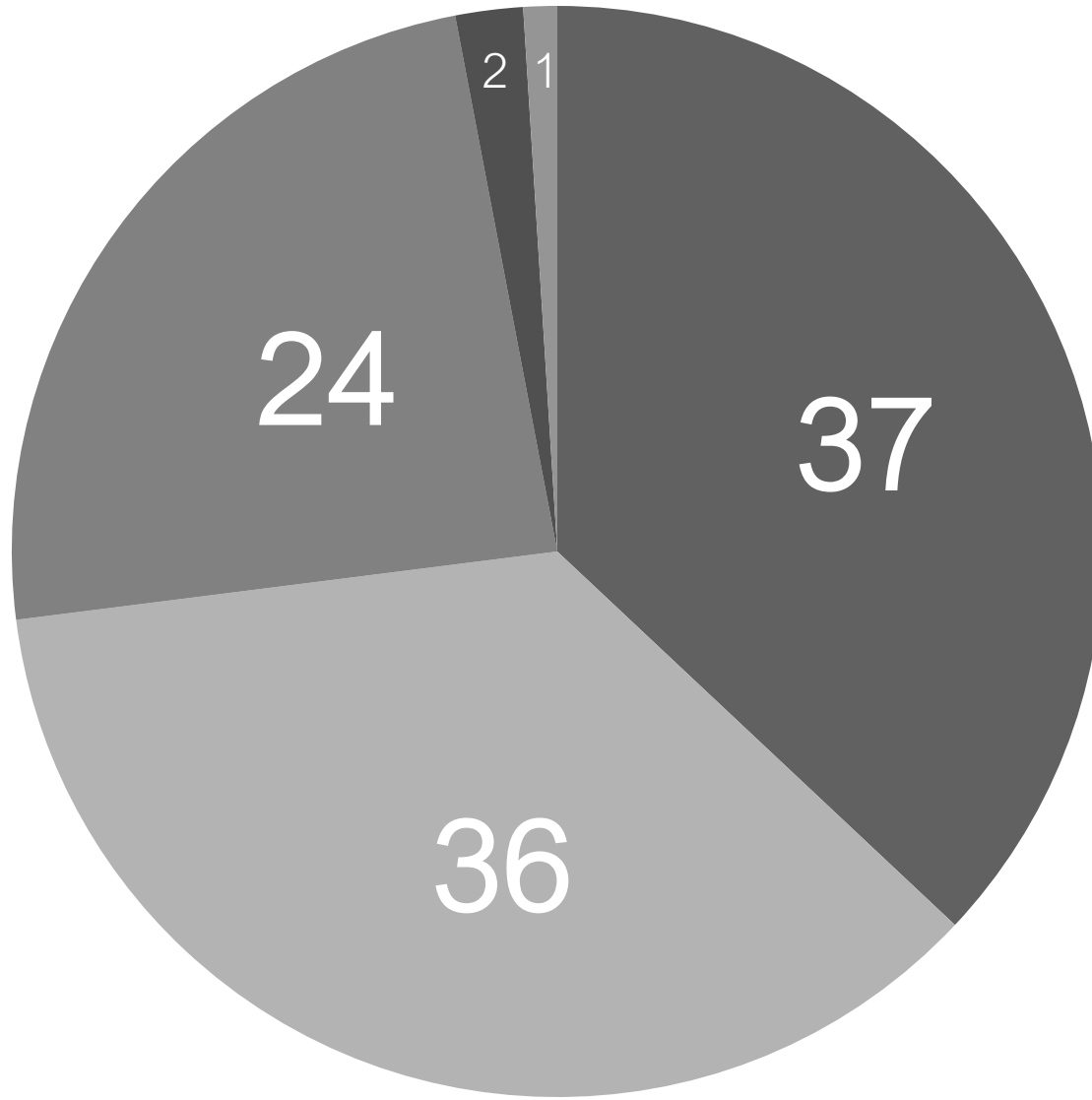


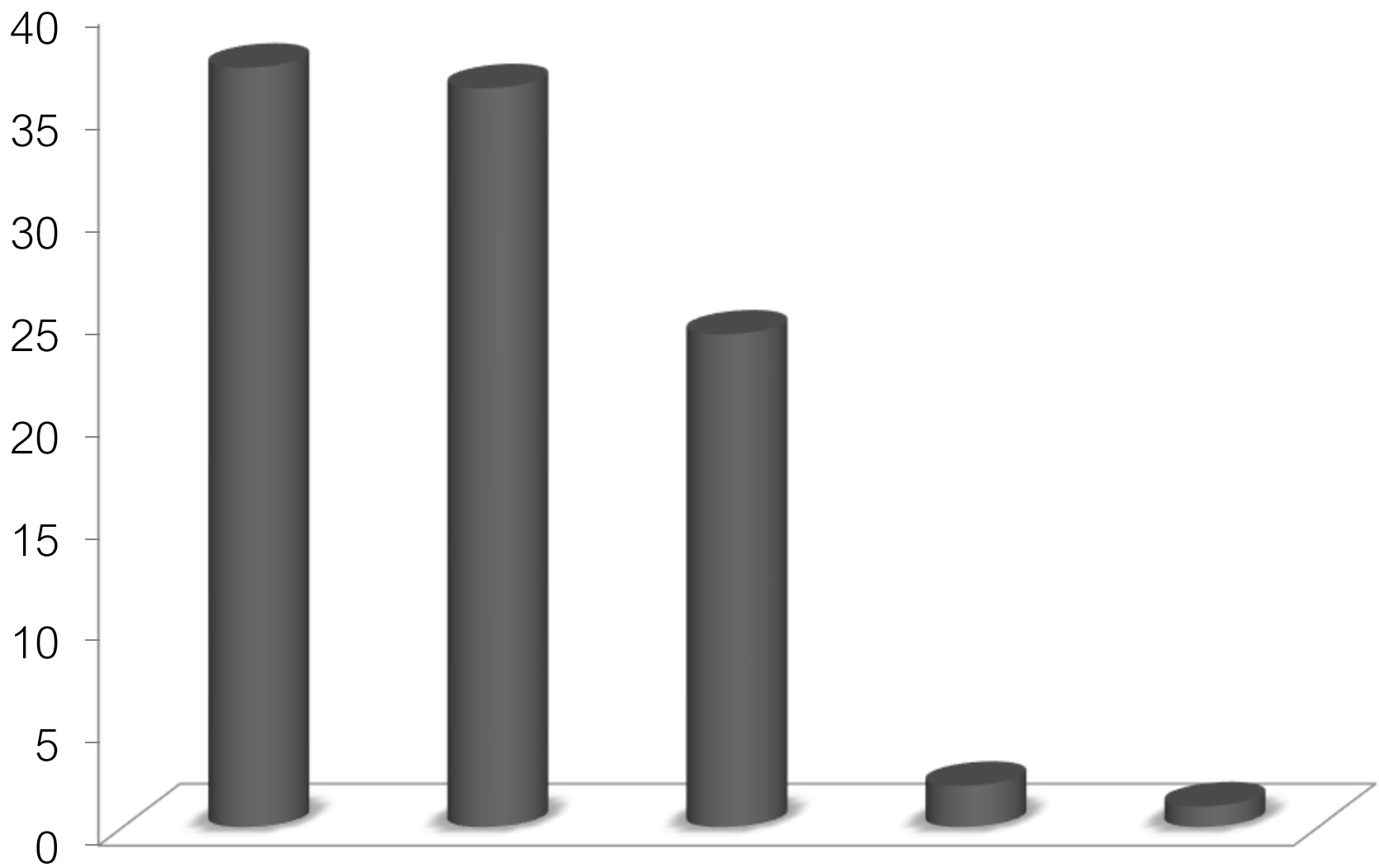


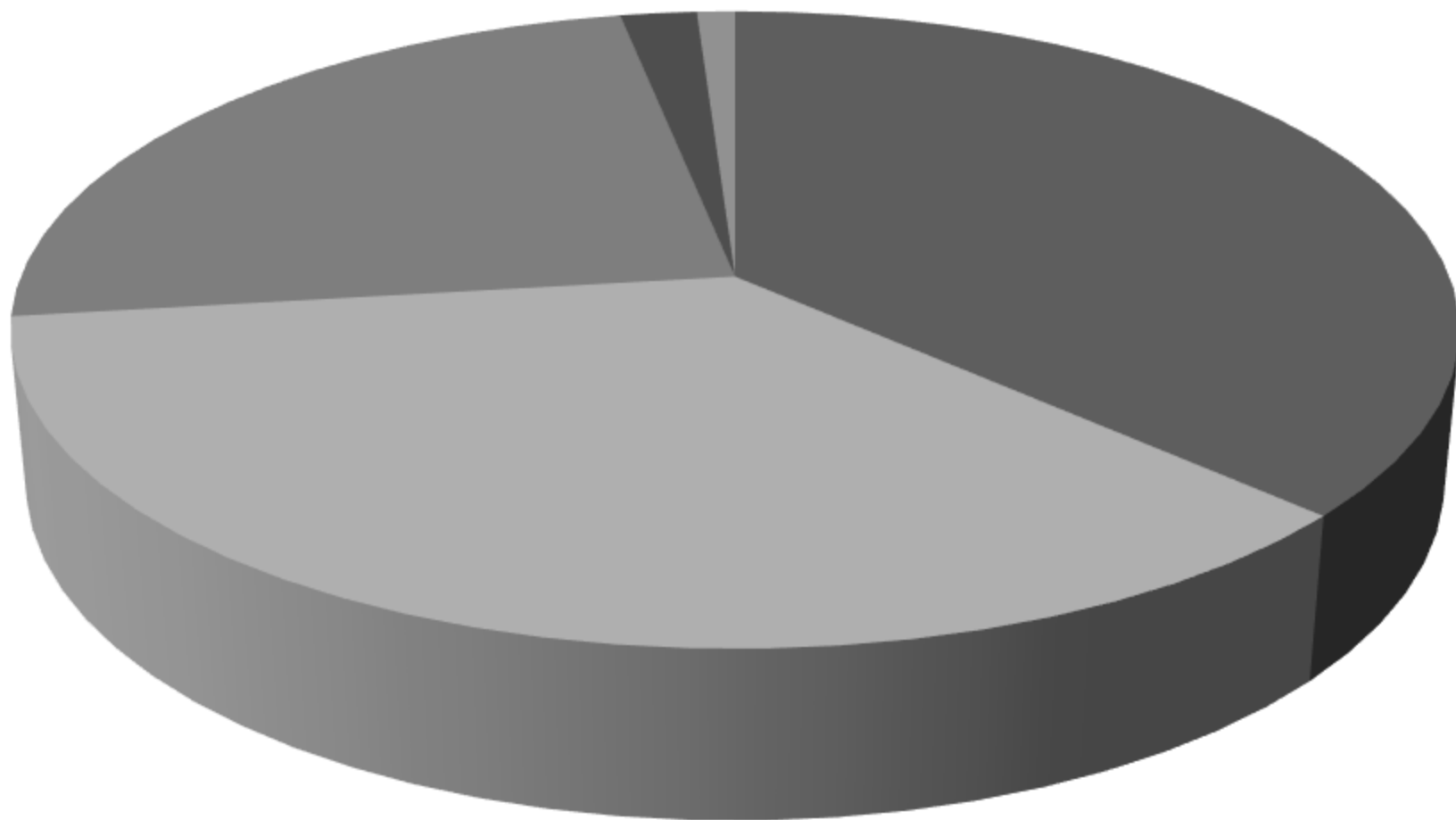
Please...

No pie charts.
No 2.5D charts.



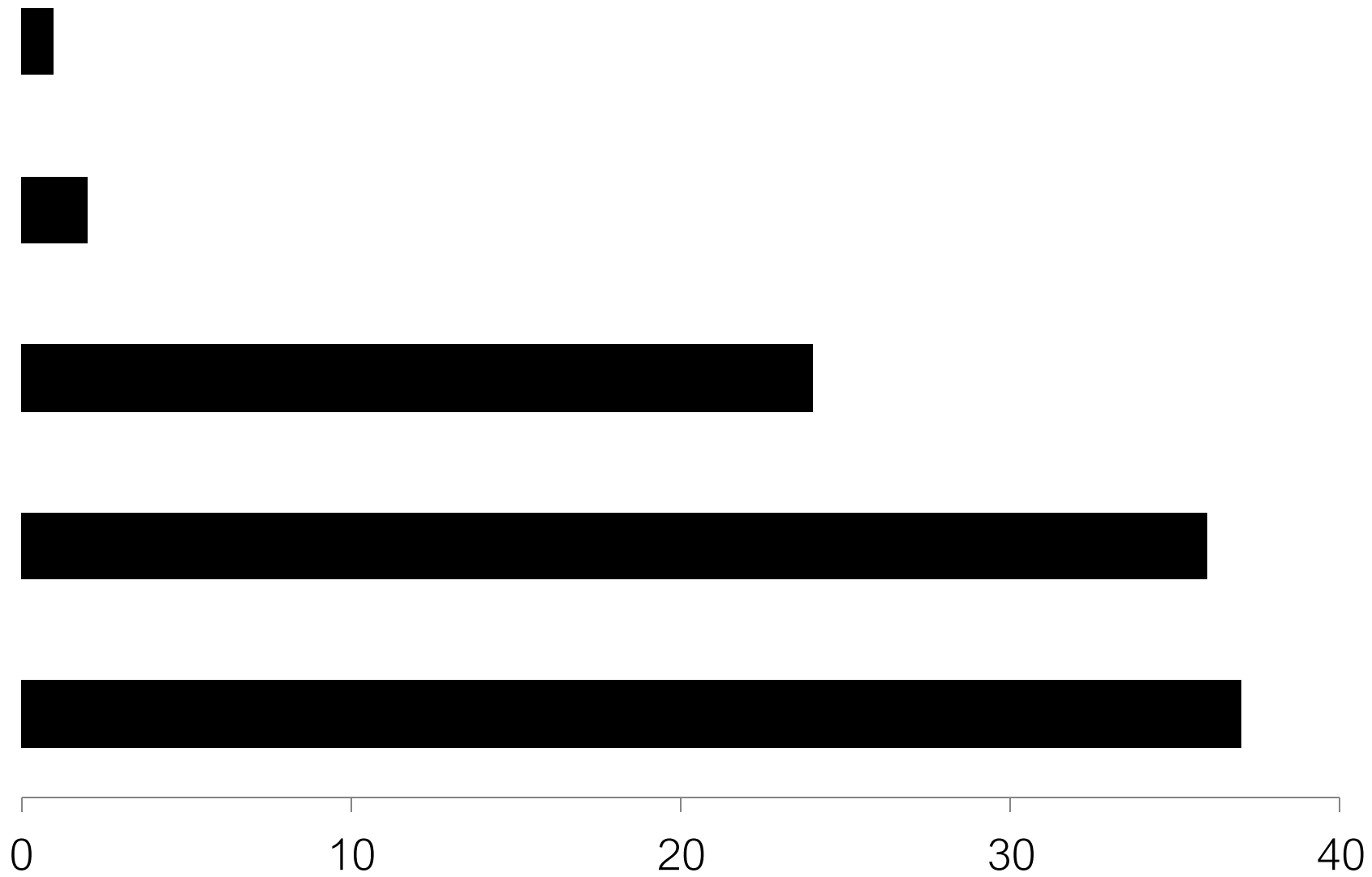




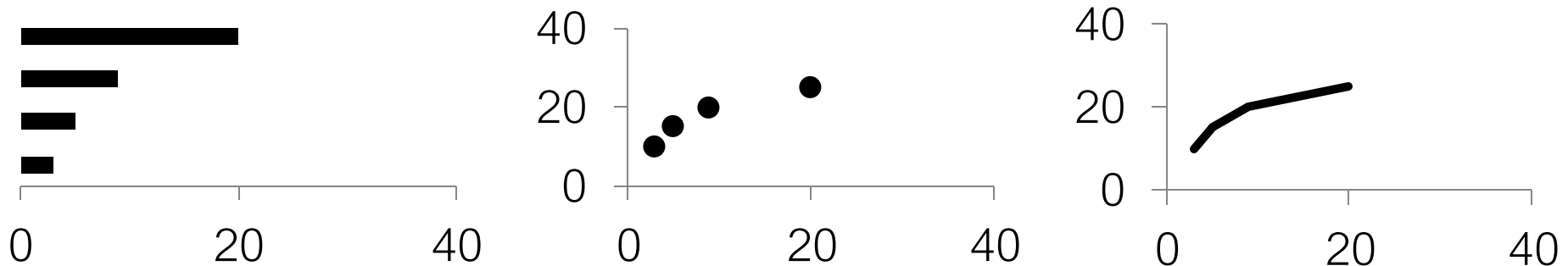




PLEASE DON'T
EVER DO THIS!



Bar charts, scatterplots, and line charts are *really effective* for quantitative data



Anyone else bored
by my color choices?

In fact, grayscale can be risky...



In fact, grayscale can be risky...



Color is Powerful

Color

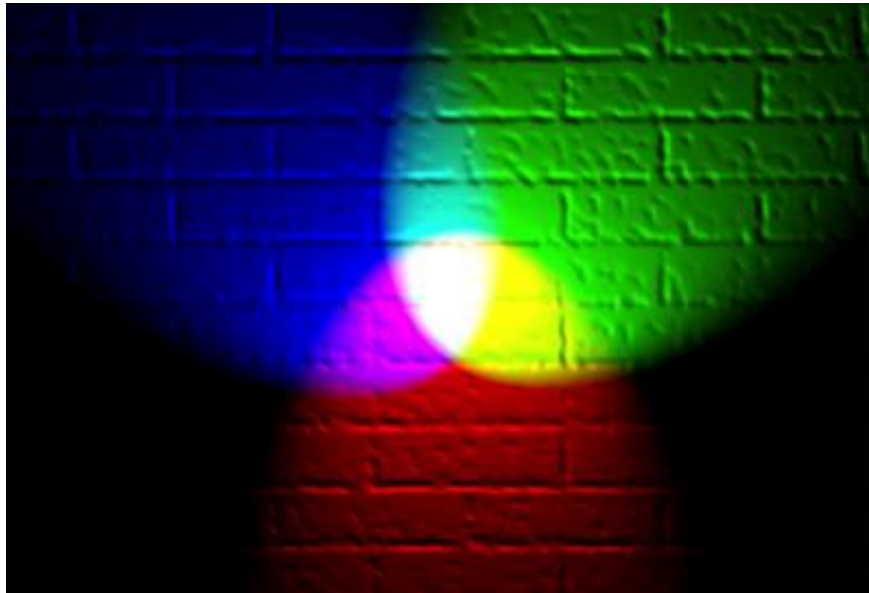
Call attention to information

Increase appeal

Increase memorability

Another dimension to work with

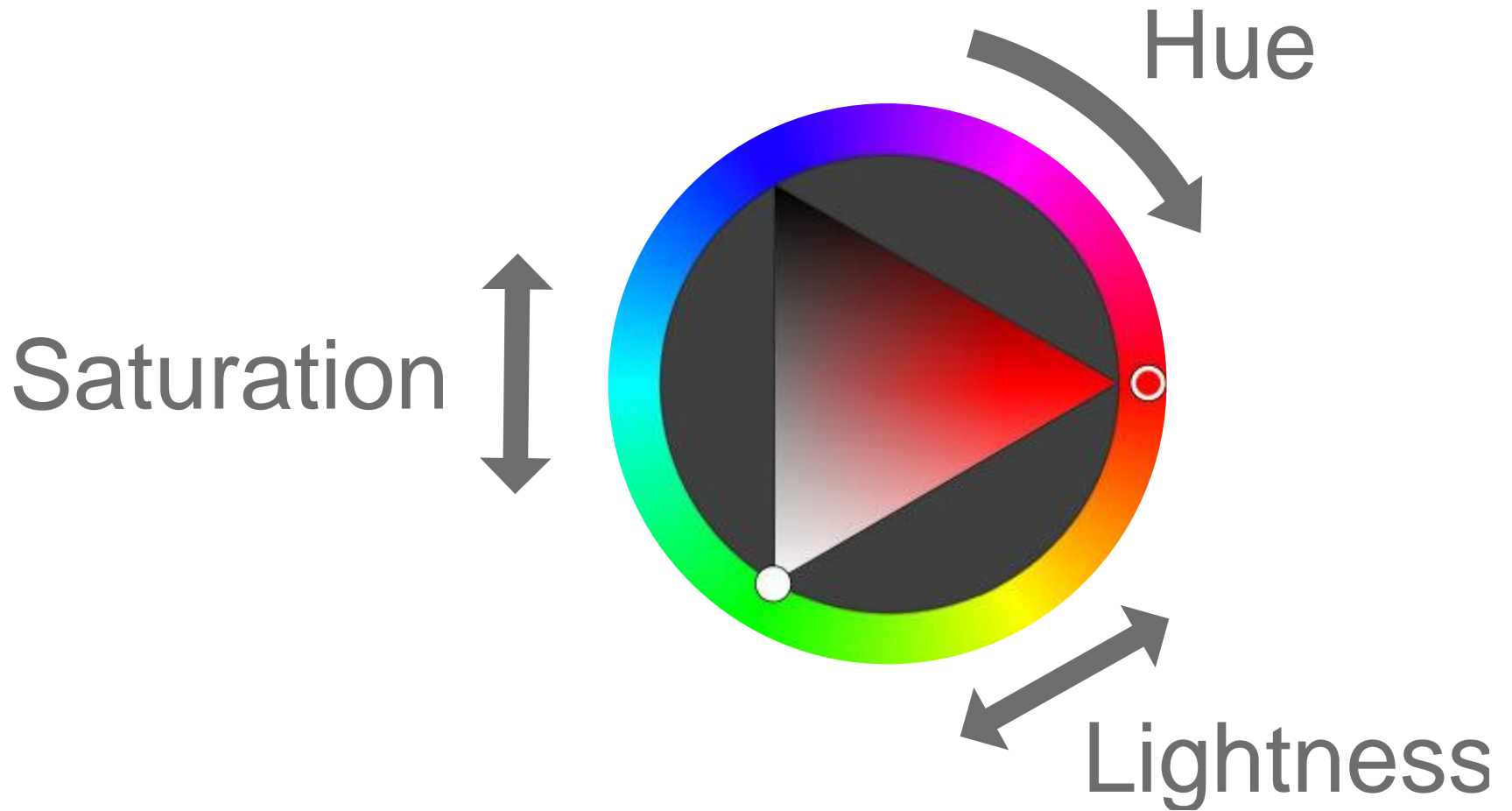
Have you heard of RGB?



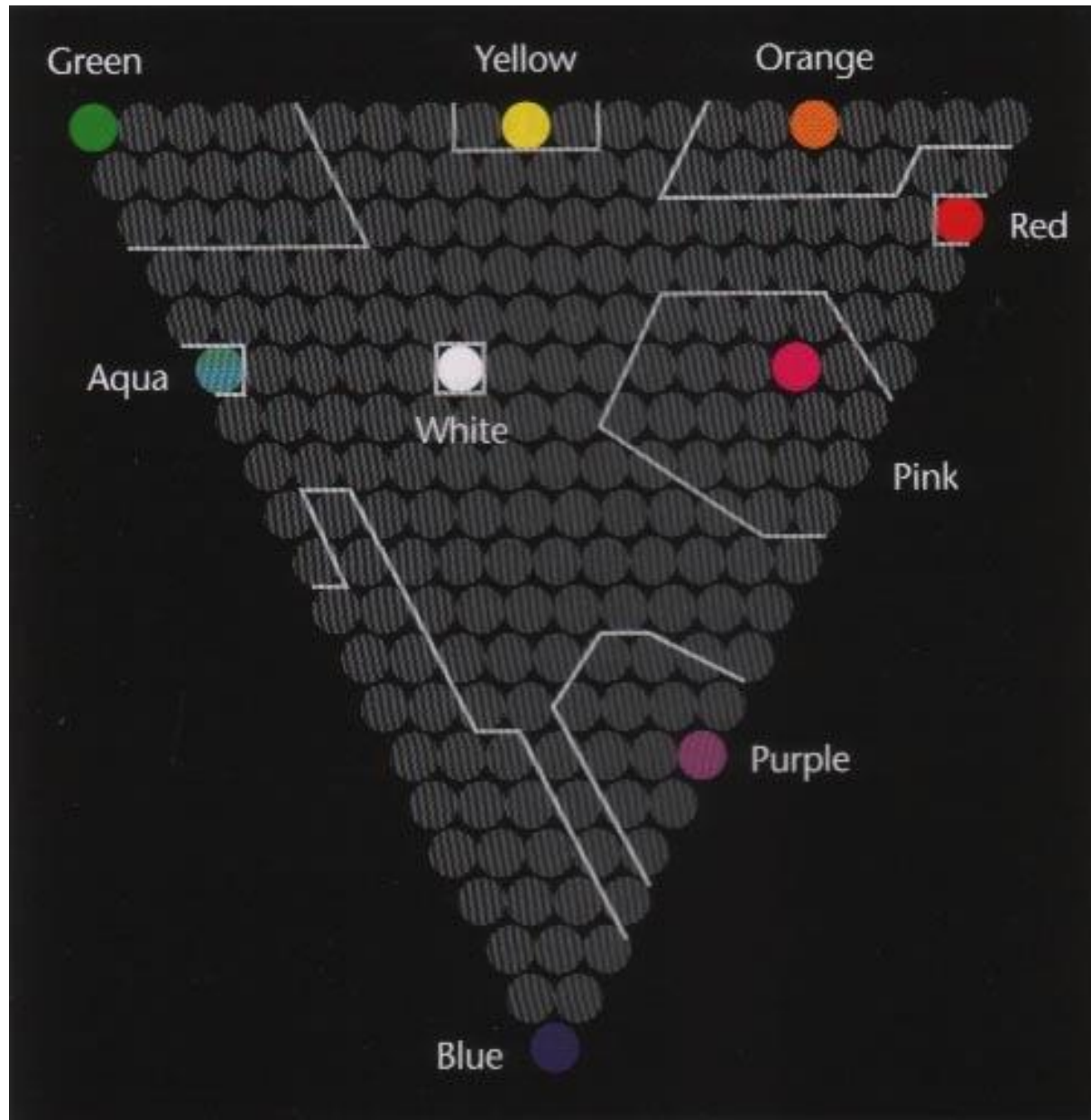
Additive color model: colors create by mixing
red, green, blue light

We see in RGB,
but we don't interpret in RGB...

HSV Color Model



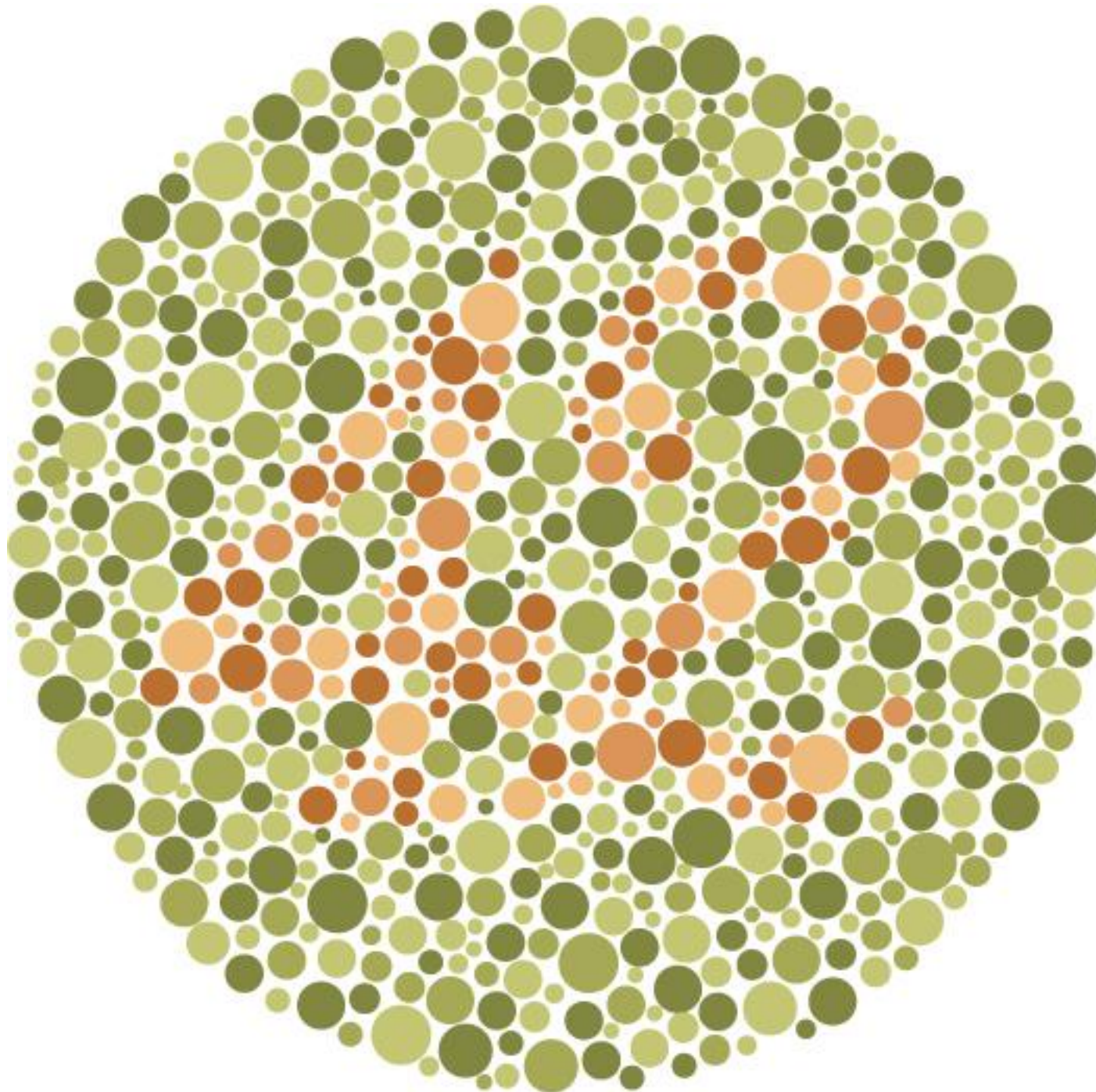
Hue

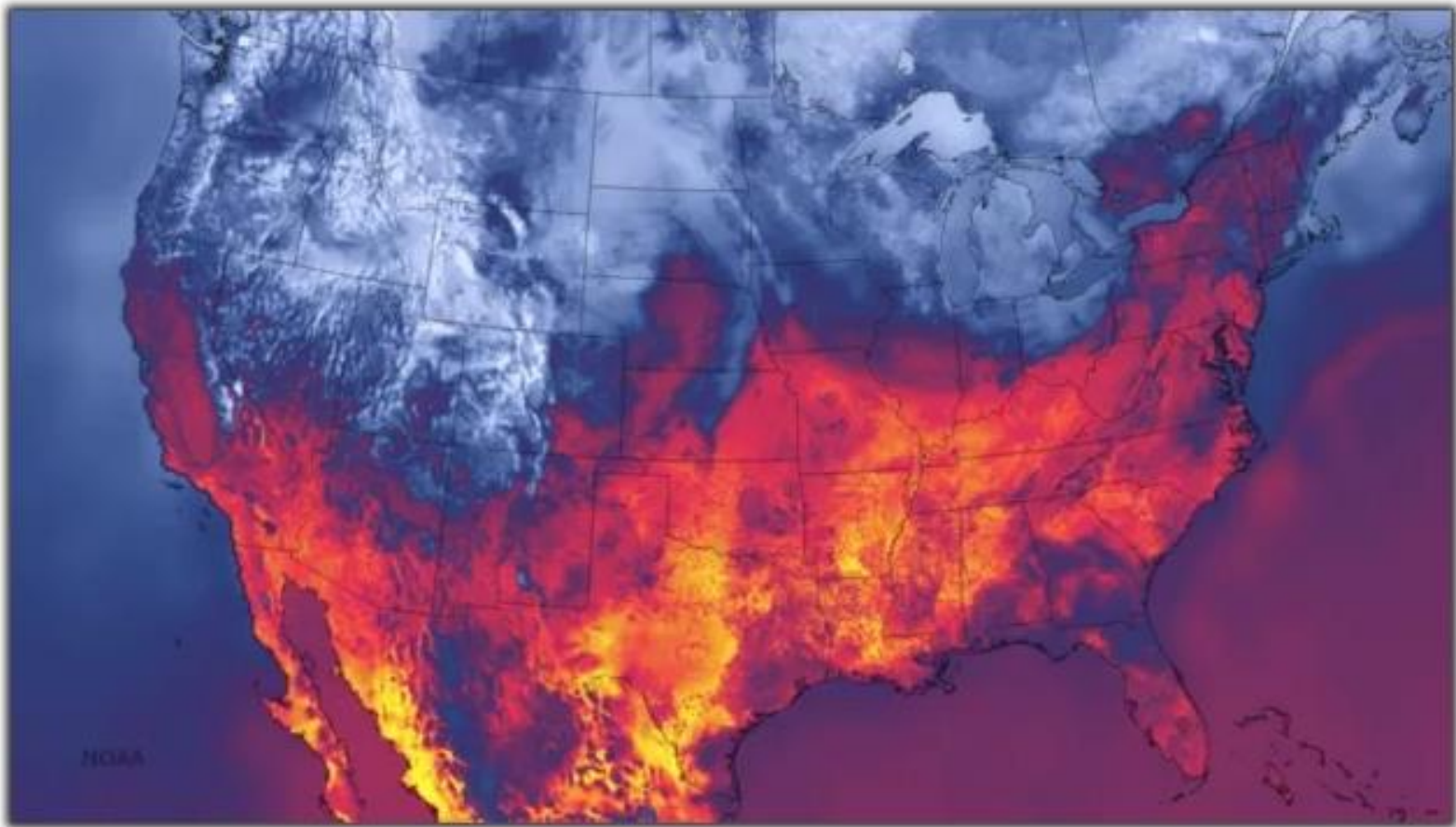


Post & Greene, 1986

Hue and Colorblindness

10% of males and 1% of females
are Red-Green Colorblind





Surface temperature (°C)



0

45

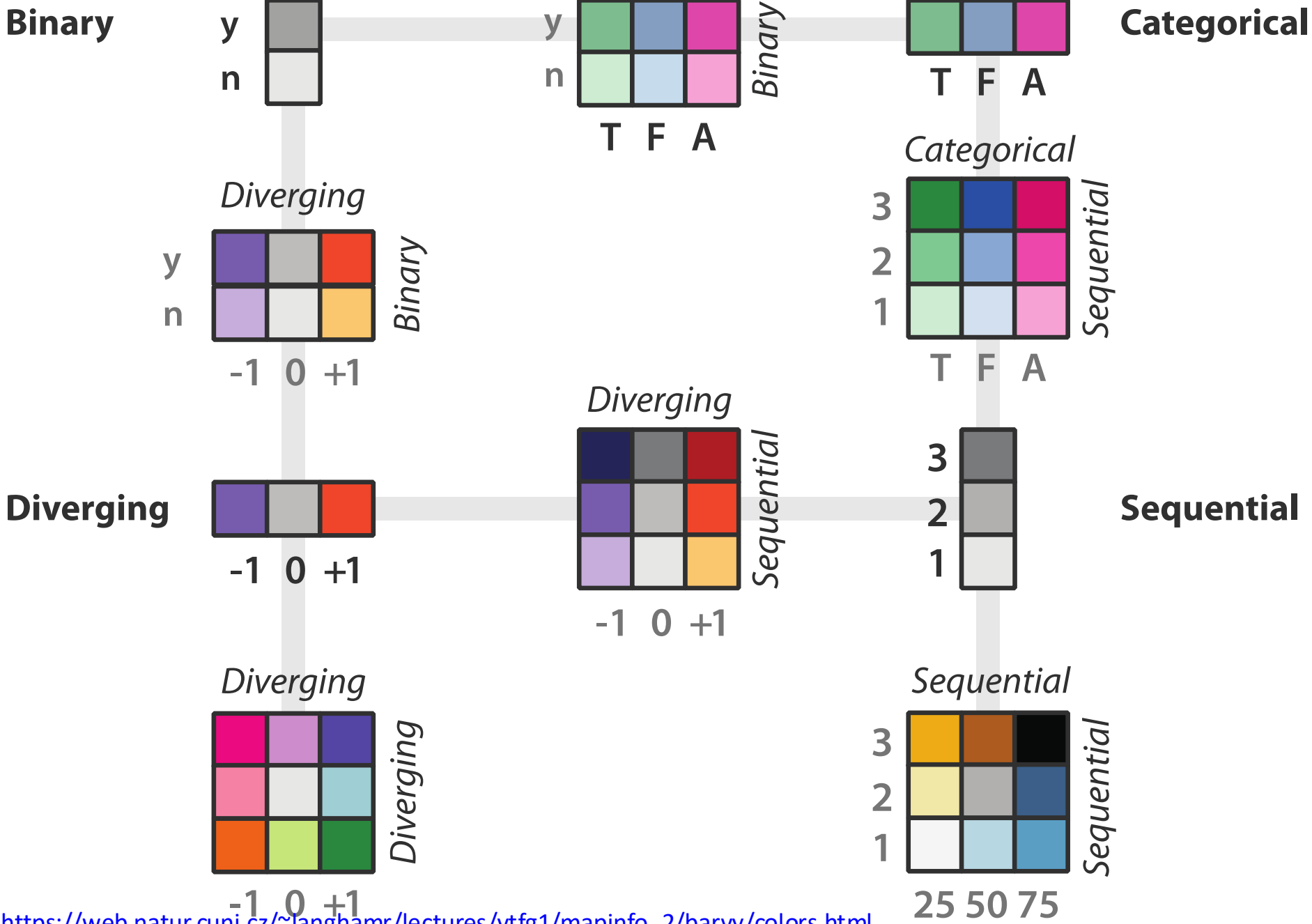
Sep 30, 2014

NOAA's Latest High Resolution Weather Model is Released

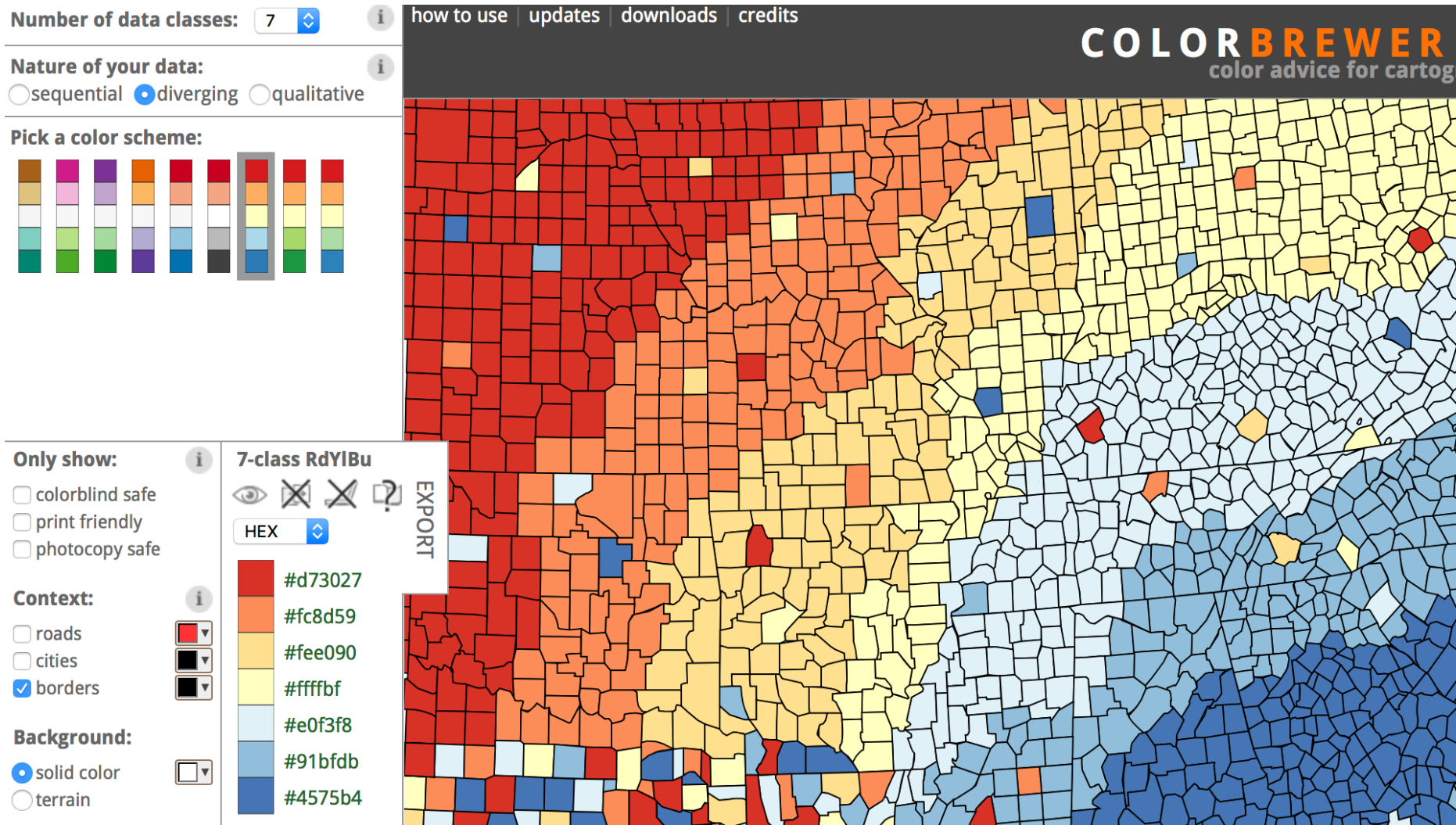
Color and Quantitative Data

Can you order these (low→hi)?





Color Brewer for Picking Color Scales



Chroma.js Color Palette Helper

This [chroma.js](#)-powered tool is here to help us [mastering multi-hued, multi-stops color scales](#).

1 What kind of palette do you want to create?

Palette type: sequential diverging

Number of colors: 11

2 Select and arrange input colors

0041ca 96ffea fffe0

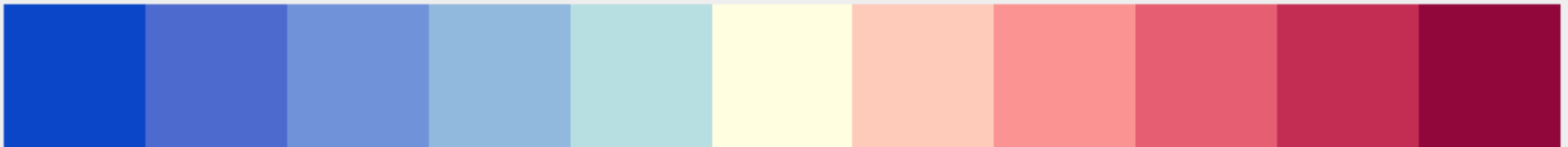
ffffe0 ff005e 93003a

3 Check and configure the resulting palette

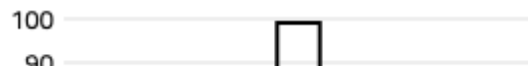
☒ correct lightness ☒ bezier interpolation

✓ This palette is colorblind-safe.

simulate: normal deut. prot. trit.



lightness



saturation



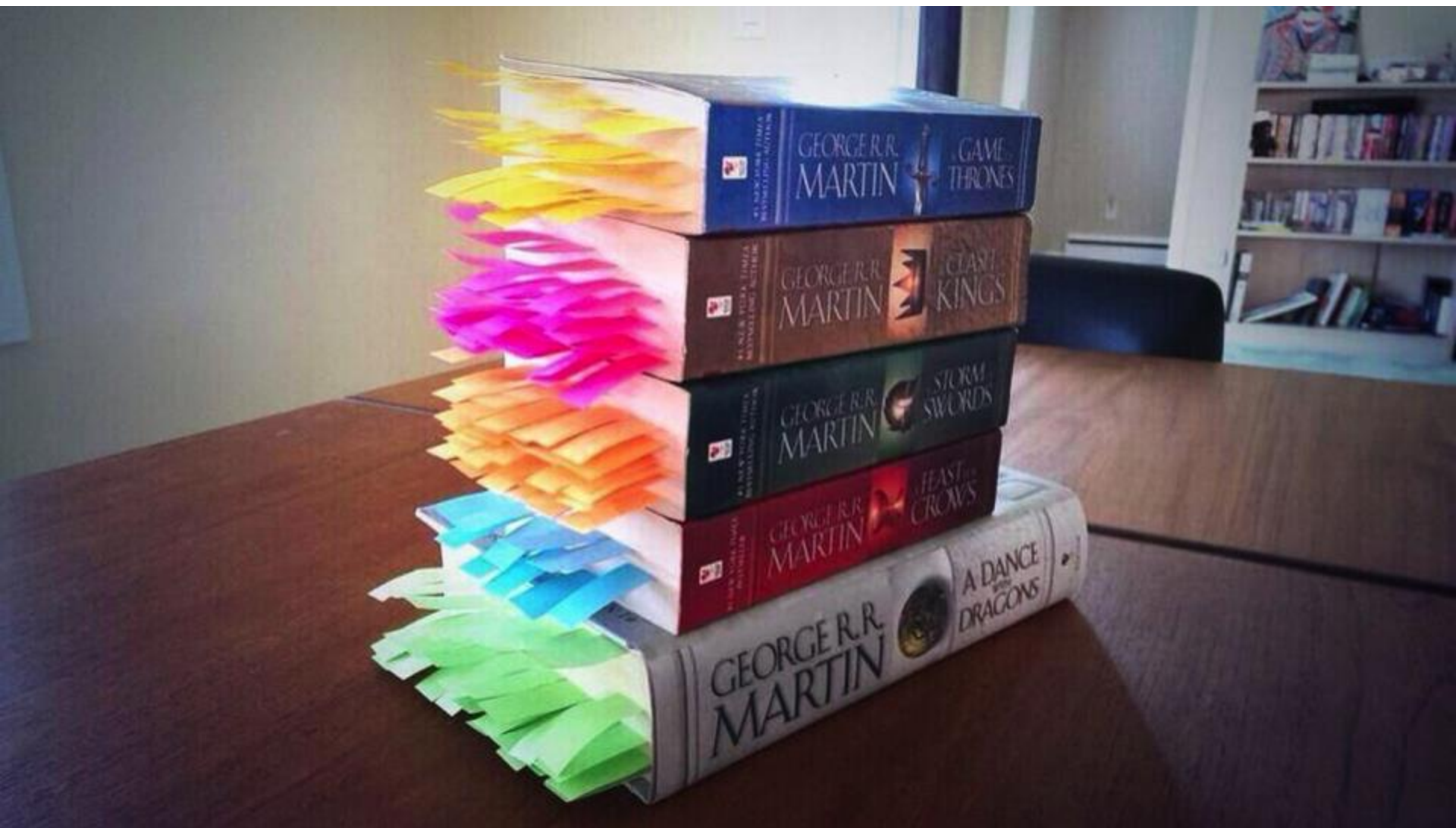
hue

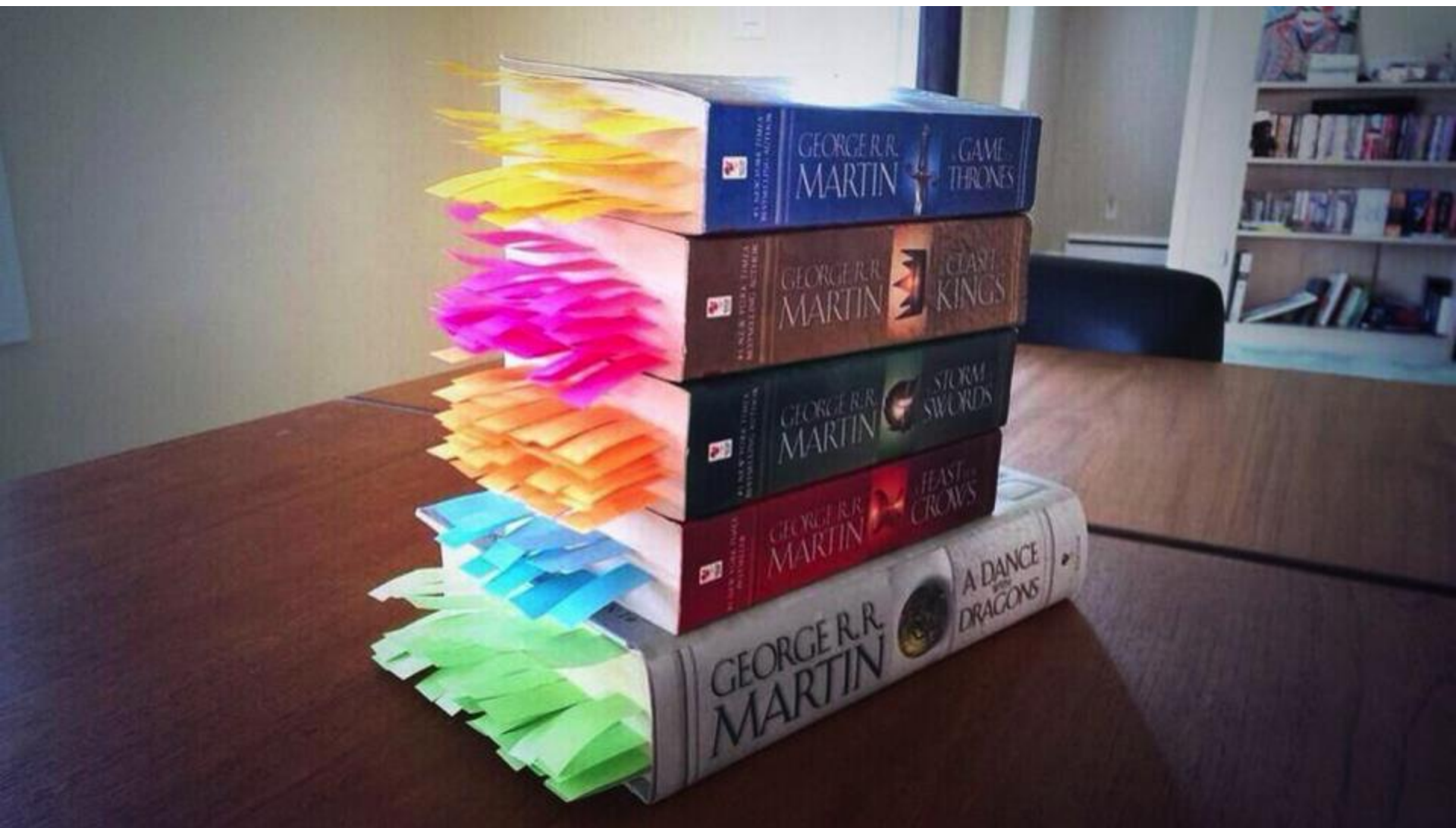


Overview Zoom+Filter Details on Demand

Shneiderman Mantra
(Information-Seeking Mantra)

<https://www.mat.ucsb.edu/g.legrady/academic/courses/11w259/schneiderman.pdf>





<http://visual.ly/every-single-death-game-thrones-series>

NameGrapher

Explore the historical popularity of United States baby names

Start typing in the lefthand text box and the graph will update. Click the option buttons for different types of results.

Tips: Be sure to check out both the “total” and “compare” views, and try multiple search terms separated by commas.

Starts with

Ends with

Contains

Exact Match

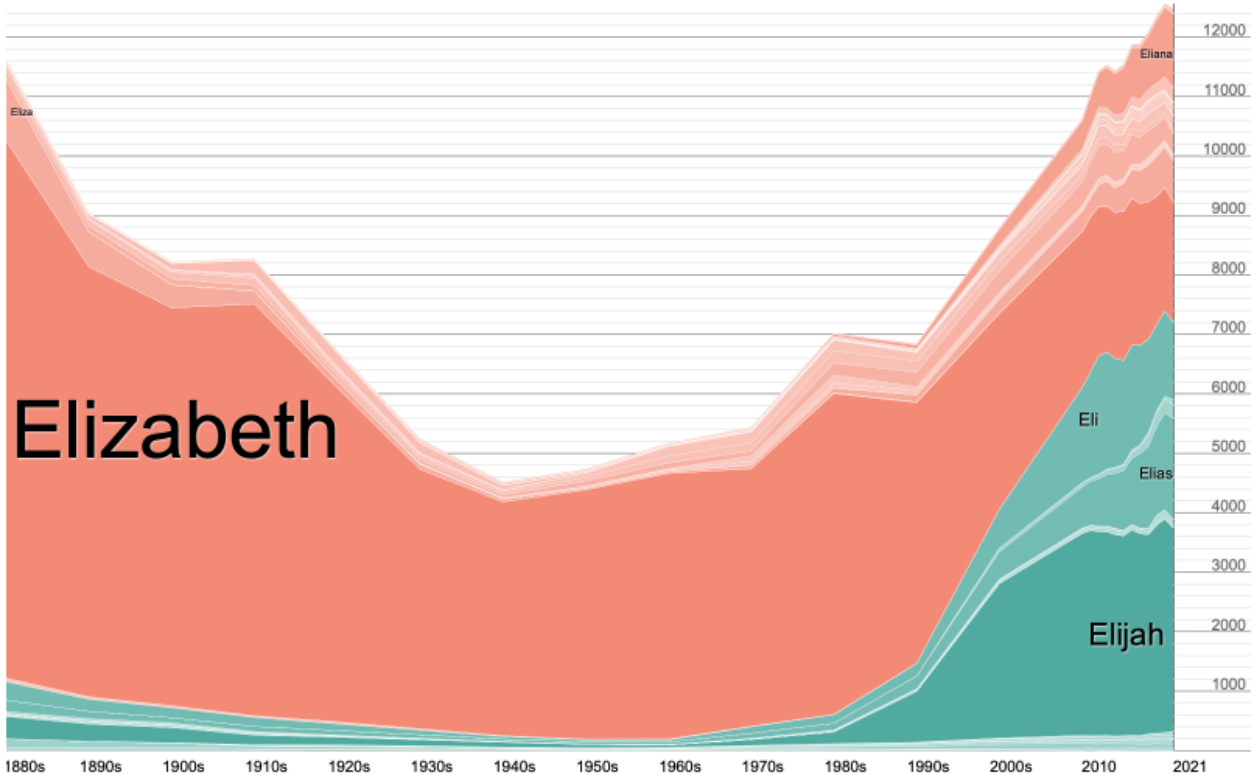
Girls

Boys

Both

Total Compare

per million births



Eli M
Elizabeth F
Elijah M
Elias M
Eliana F
Eliza F
Elise F
Elisa F
Elisabeth F
Elianna F
Elian M
Elisha M
Elinor F
Elissa F
Eliseo M

And 31 more...

NameVoyager: Explore baby names and name trends letter by letter

Looking for the perfect baby name? **Sign up for free** to receive access to our expert tools!

Baby Name > ☒ Both ☐ Boys ☐ Girls

Current rank: boys

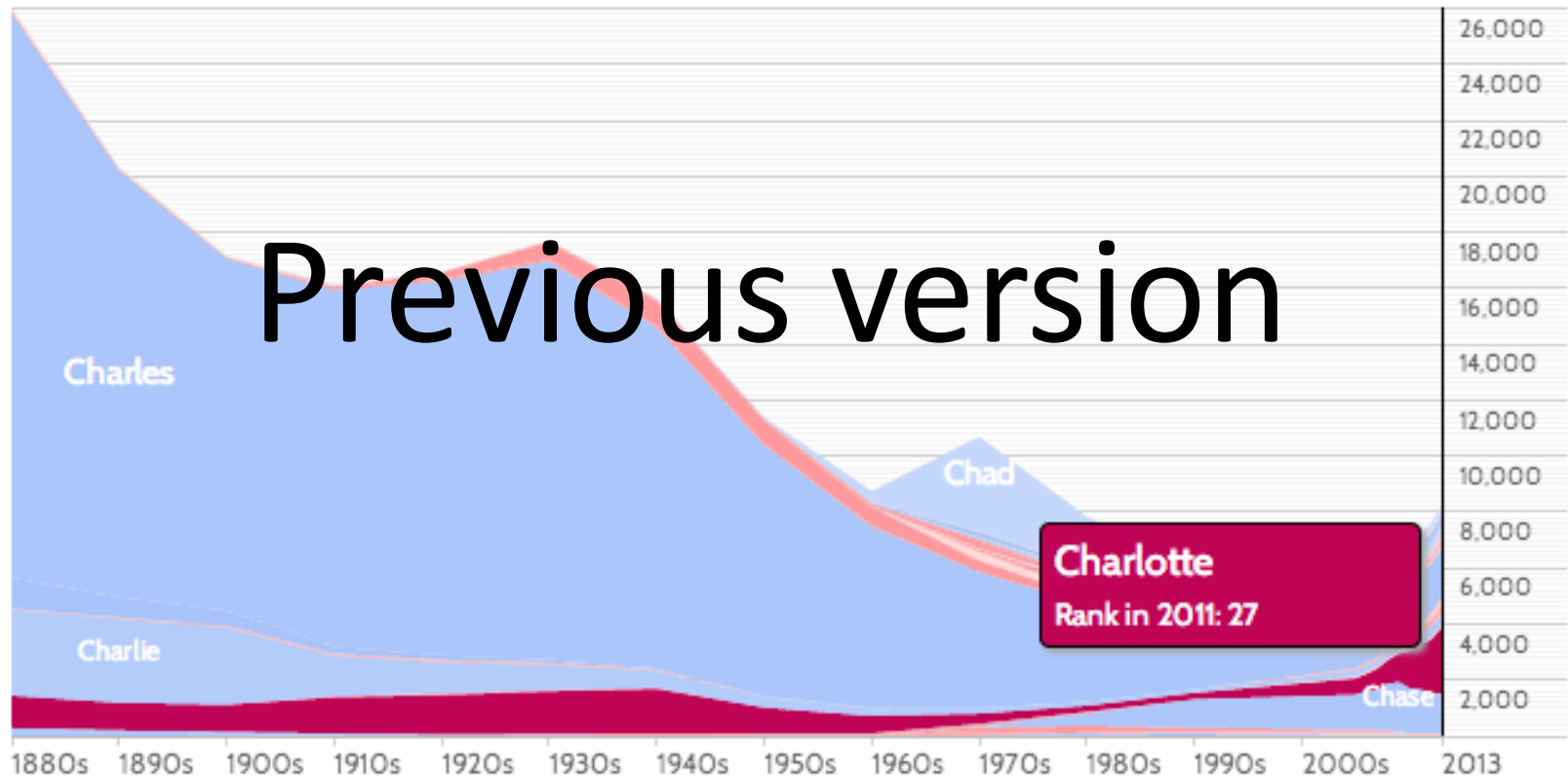
1000	500	100	25	1
------	-----	-----	----	---

girls

1000	500	100	25	1
------	-----	-----	----	---

Names starting with 'CHA' per million babies

per million births



Click a name graph to view that name. Double-click to read more about it.

[enlarge](#)

Where to learn more?

Georgia Tech Visualization Group

vis.gatech.edu



Alex Endert

Associate Professor

visual analytics

information visualization

coffee



Clio Andris

Associate Professor

geographic information systems

urban analytics

bunnies



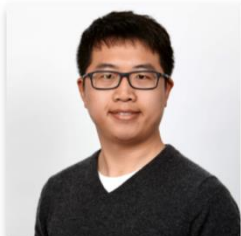
John Stasko

Regents Professor

information visualization

multimodal interaction

golf



Yalong Yang

Assistant Professor

VR/AR

immersive analytics

embodied interaction

cartoon



Cindy Xiong Bearfield

Assistant Professor

information visualization

perception and cognition

trust

mango



James Foley

Professor Emeritus

human-computer interaction

computer graphics

trains



Polo Chau

Associate Professor

human-centered AI

AI security

graph visualization

cellist



Affiliated Faculty



Haesun Park

Regents Professor



Jessica Roberts

Assistant Professor



Our Courses

We offer classes in Information Visualization and Visual Analytics for undergraduates as well as graduates in the Spring and Fall semesters.

Undergraduate

CS 4460 : Introduction to Information Visualization

Fall

Spring

CX 4242 : Data and Visual Analytics

Fall

Spring

Graduate

CS 6730 : Data Visualization: Principles and Applications

Fall

CS 7450 : Information Visualization

Spring

CS 7451 : Human-Centered Data Analysis

Spring

CSE 6242 : Data and Visual Analytics

Fall

Spring

CP 8883 : Spatial Network Analysis

Spring

<https://vis.gatech.edu/courses/>

How to Make Good Charts

- Edward Tufte's One-Day Workshop
 - <http://www.edwardtufte.com/tufte/courses>
- Edward Tufte, *Visual Display of Quantitative Information*
 - http://www.edwardtufte.com/tufte/books_vdqi
- Stephen Few, *Show Me the Numbers: Designing Tables and Graphs to Enlighten*
 - http://www.amazon.com/Show-Me-Numbers-Designing-Enlighten/dp/0970601972/ref=la_B001H6IQ5M_1_2?s=books&ie=UTF8&qid=1385050724&sr=1-2

Visualization Theory “Books”

- Tamara Munzner VIS Tutorial and Book
 - <http://www.cs.ubc.ca/~tmm/talks.html>
 - <http://www.cs.ubc.ca/~tmm/vadbook/>
- Colin Ware, *Information Visualization: Perception for Design*
 - <http://www.amazon.com/Information-Visualization-Perception-Interactive-Technologies/dp/1558605118>
- Stephen Few, *Now You See It*
 - http://www.amazon.com/Now-You-See-Visualization-Quantitative/dp/0970601980/ref=pd_bxgy_b_img_z
- Edward Tufte, *Envisioning Information*
 - http://www.edwardtufte.com/tufte/books_ei
- Edward Tufte, *Visual Explanations*
 - http://www.edwardtufte.com/tufte/books_visex
- Edward Tufte, *Beautiful Evidence*
 - http://www.edwardtufte.com/tufte/books_be
- Tamara Munzner, *Visualization Analysis & Design*
 - <http://www.amazon.com/Visualization-Analysis-Design-AK-Peters/dp/1466508914>

Perception and Color Websites

- Chris Healy, NC State
 - <http://www.csc.ncsu.edu/faculty/healey/PP/index.html>
- Color Brewer
 - <http://colorbrewer2.org/>
- Maureen C. Stone (Color Links, Blog, Workshops)
 - <http://www.stonesc.com/color/index.htm>
- Subtleties of Color by Robert Simmon of NASA
 - <http://blog.visual.ly/subtleties-of-color/>

Visualization Blogs

- Flowing Data by Nathan Yau
 - <http://flowingdata.com/>
- Information Aesthetics by Andrew Vande Moere
 - <http://infosthetics.com/>
- Information is Beautiful by David McCandless
 - <http://www.informationisbeautiful.net/>
- Visual.ly Blog
 - <http://blog.visual.ly/>
- Indexed Comic by Jessica Hagy
 - <http://thisisindexed.com/>

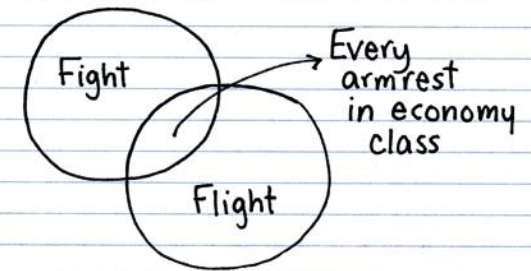
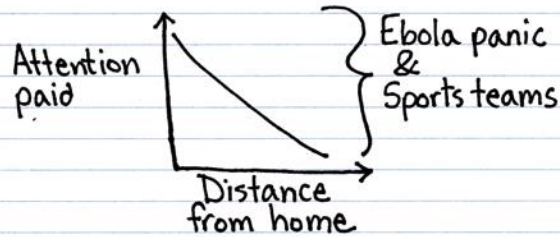
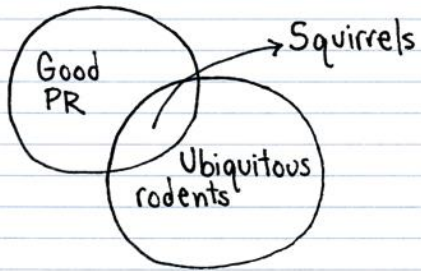
Infographics

[Visual.ly/view](#)
([wtfviz.net](#))

Thanks!

Chad Stolper

chadstolper@gatech.edu



Questions?

 Chad Stolper

chadstolper@gatech.edu