

# Design principles

Chen He

# After this lecture, you will be able to

**Name** the ways to organize information;

**Discuss/critique** existing visualization designs based on the learned principles.

# Spirited Away (2001)

★ 8.6 / 498,533

Sen to Chihiro no kamikakushi (original title)

PG | 2h 5min | Animation, Adventure, Family | 28 March 2003 (USA)

During her family's move to the suburbs, a sullen 10-year-old girl wanders into a world ruled by gods, witches, and spirits, where humans are changed into beasts.

**Directors:** Hayao Miyazaki, Kirk Wise

**Writer:** Hayao Miyazaki

**Stars:** Daveigh Chase, Suzanne Plésio, Ryouu Irino  
See full cast & crew »



Directors  
Genre Time Length

# The Pursuit of Happyness (2006)

★ 8.0 / 380,378

PG-13 | 1h 57min | Biography, Drama | 15 December 2006 (USA)



A struggling salesman takes custody of his son as he's poised to begin a life-changing professional career.

**Director:** Gabriele Muccino

**Writer:** Steve Conrad (as Steven Conrad)

**Stars:** Will Smith, Thandie Newton, Jaden Smith |  
See full cast & crew »

Stars  
Country Rating

# The Matrix (1999)

★ 8.7 / 1,383,370

R | 2h 16min | Action, Sci-Fi | 31 March 1999 (USA)

A computer hacker learns from mysterious rebels about the true nature of his reality and his role in the war against its controllers.

**Directors:** Lana Wachowski (as The Wachowski Brothers), Lilly Wachowski (as The Wachowski Brothers)

**Writers:** Lilly Wachowski (as The Wachowski Brothers), Lana Wachowski (as The Wachowski Brothers)

**Stars:** Keanu Reeves, Laurence Fishburne, Carrie-Anne Moss  
See full cast & crew »



73 Metascore From metacritic.com | 3,811 user | 323 critic | Popularity 308

# Memento (2000)

★ 8.5 / 959,472

R | 1h 53min | Mystery, Thriller | 25 May 2001 (USA)



A man juggles searching for his wife's murderer and coping with short-term memory loss from being an obstacle.

**Director:** Christopher Nolan

**Writers:** Christopher Nolan (screenplay), Jonathan Nolan (story "Memento Mori")

**Stars:** Guy Pearce, Carrie-Anne Moss, Joe Pantoliano  
See full cast & crew »

From millions of movies,  
how do you find interesting movies to watch?

Genre

Time

Length

Country

Rating

Directors

Stars

# The L.A.T.C.H principle -- Methods of organization

Information may be infinite, however... the organization of information is finite.

Location

Alphabet

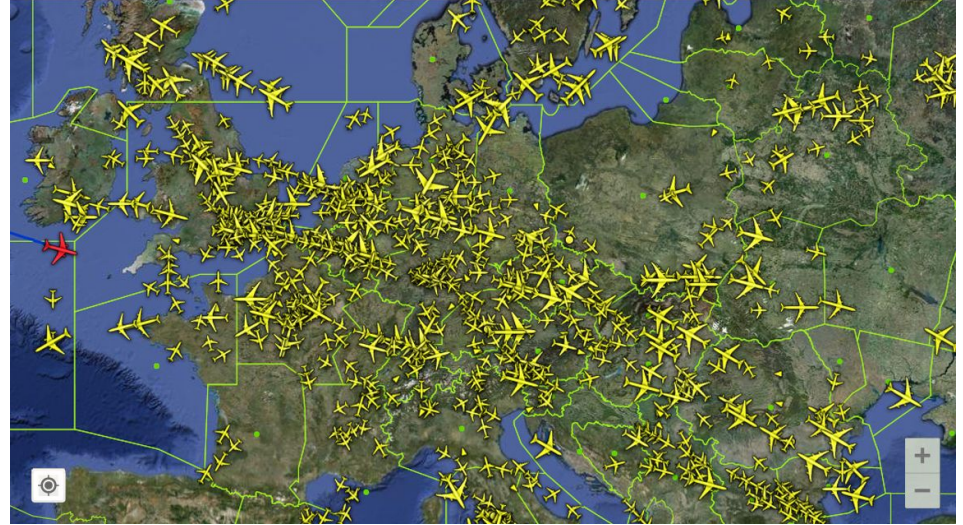
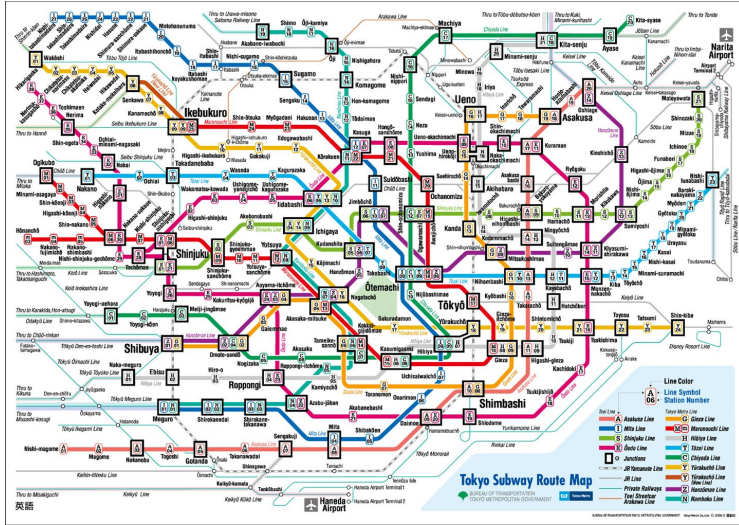
Time

Category

Hierarchy

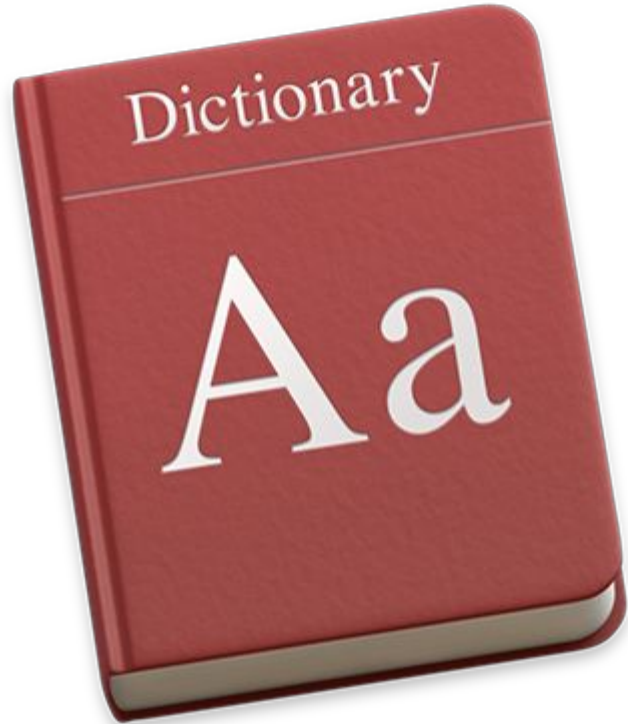


# The L.A.T.C.H principle -- Location

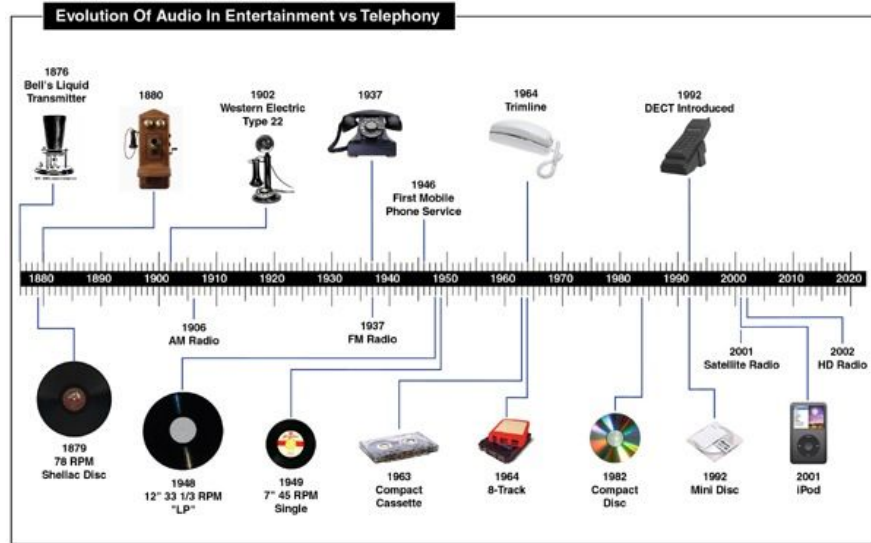
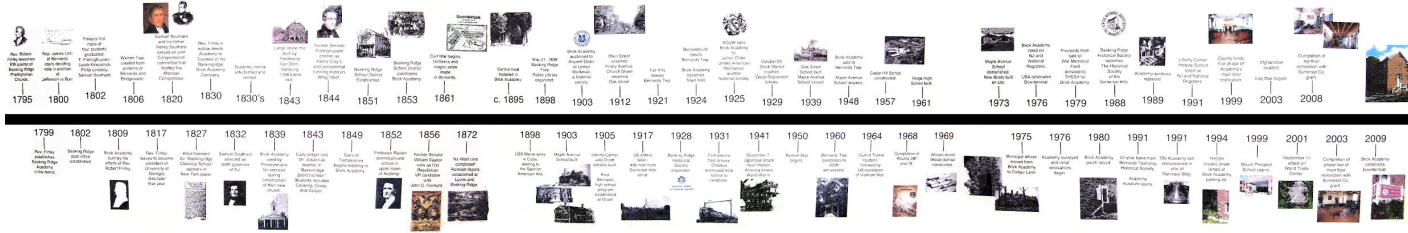


# The L.A.T.C.H principle -- **A**lphabet

Use when no other methods are appropriate.



# The L.A.T.C.H principle -- Time



JANUARY 2017	FEBRUARY 2017	MARCH 2017	APRIL 2017
S M T W T F S	S M T W T F S	S M T W T F S	S M T W T F S
1 2 3 4 5 6 7	1 2 3 4	1 2 3 4	1 2 3 4
8 9 10 11 12 13 14	5 6 7 8 9 10 11	5 6 7 8 9 10 11	2 3 4 5 6 7 8
15 16 17 18 19 20 21	12 13 14 15 16 17 18	12 13 14 15 16 17 18	9 10 11 12 13 14 15
22 23 24 25 26 27 28	19 20 21 22 23 24 25	19 20 21 22 23 24 25	16 17 18 19 20 21 22
29 30 31	26 27 28	26 27 28 29 30 31	23 24 25 26 27 28 29 30

MAY 2017	JUNE 2017	JULY 2017	AUGUST 2017
S M T W T F S	S M T W T F S	S M T W T F S	S M T W T F S
1 2 3 4 5 6	1 2 3 4	1 2 3 4	1 2 3 4 5
7 8 9 10 11 12 13	4 5 6 7 8 9 10	2 3 4 5 6 7 8	6 7 8 9 10 11 12
14 15 16 17 18 19 20	11 12 13 14 15 16 17	9 10 11 12 13 14 15	13 14 15 16 17 18 19
21 22 23 24 25 26 27	18 19 20 21 22 23 24	16 17 18 19 20 21 22	20 21 22 23 24 25 26
28 29 30 31	25 26 27 28 29 30	23 24 25 26 27 28 29 30 31	27 28 29 30 31

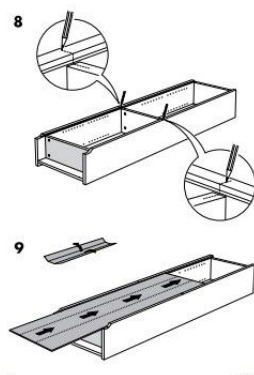
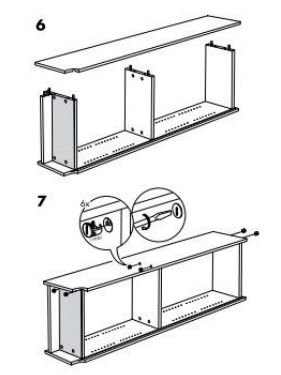
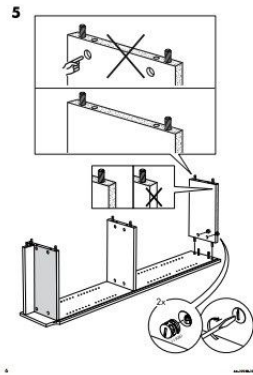
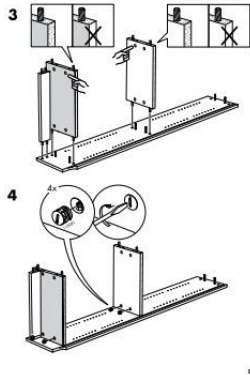
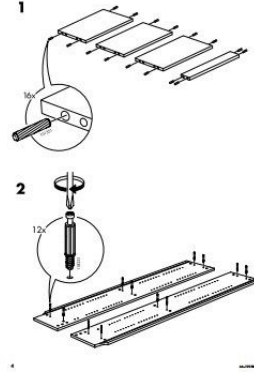
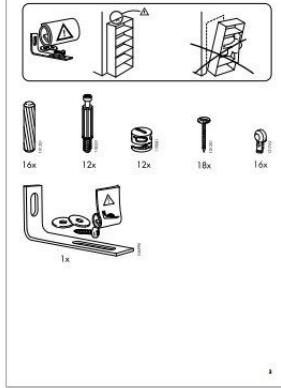
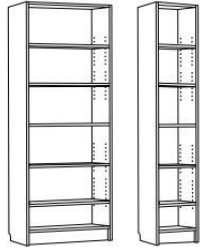
  

SEPTEMBER 2017	OCTOBER 2017	NOVEMBER 2017	DECEMBER 2017
S M T W T F S	S M T W T F S	S M T W T F S	S M T W T F S
1 2	1 2 3 4 5 6 7	1 2 3 4	1 2
3 4 5 6 7 8 9	8 9 10 11 12 13 14	5 6 7 8 9 10 11	3 4 5 6 7 8 9
10 11 12 13 14 15 16	15 16 17 18 19 20 21	12 13 14 15 16 17 18	10 11 12 13 14 15 16
17 18 19 20 21 22 23	22 23 24 25 26 27 28	19 20 21 22 23 24 25	17 18 19 20 21 22 23
24 25 26 27 28 29 30	29 30 31	26 27 28 29 30	24 25 26 27 28 29 30 31

■ TSS School Holidays 
 ■ Public Holidays observed by TSS 
 ■ TSS Student Free Days

# The L.A.T.C.H principle -- Time

## BILLY



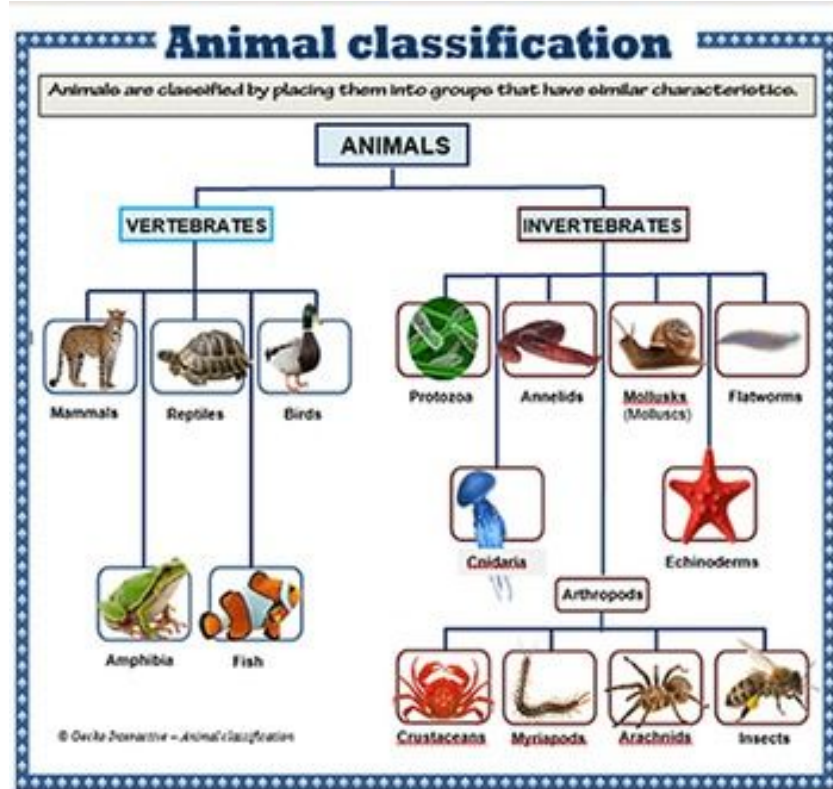
# The L.A.T.C.H principle -- Category

Organize by similarity or relatedness.

Group	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Period	1 1 H																	2 He
2	3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
3	11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
4	19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
5	37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
6	55 Cs	56 Ba	57 La	* 72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
7	87 Fr	88 Ra	89 Ac	* 104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Nh	114 Fl	115 Mc	116 Lv	117 Ts	118 Og
				* 58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu	
				* 90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr	

# The L.A.T.C.H principle -- Hierarchy

▼ afoo	Today, 23:44
▼ cohort	Today, 23:28
▼ main	Today, 22:41
app.yaml	Yesterday, 10:23
index.yaml	Apr 7, 2016, 10:15
main.go	Today, 12:06
▼ scripts	Today, 14:49
adjacency.js	Today, 22:18
force.js	Today, 10:48
heb.js	Today, 22:13
utils.js	Today, 11:28
▼ styles	Today, 14:49
heb.css	Apr 6, 2016, 12:54
main.css	Today, 11:34
map.css	Yesterday, 22:20
student.css	Mar 30, 2016, 17:38
▼ views	Today, 14:49
▶ admin	Apr 2, 2016, 12:41
▶ main	Today, 14:49
master.html	Today, 11:45
▼ models	Today, 14:49
display.go	Today, 10:49
student.go	Apr 8, 2016, 08:02
▼ repository	Today, 23:37
repository.go	Apr 10, 2016, 15:56
▼ utils	Apr 4, 2016, 15:31
log.go	Apr 4, 2016, 15:31
utils.go	Apr 8, 2016, 10:24



# The L.A.T.C.H principle -- Benefits?

Maximize visual working memory: ~~Four items~~ four chunks;

Support information navigation and exploration;

# The L.A.T.C.H principle -- VisGets

**Search**

**Collection** Global Voices Online

[About](#) [Help](#)

**Time** ✕

Years

Months

Days

**Location** + 🌐

POWERED BY Google

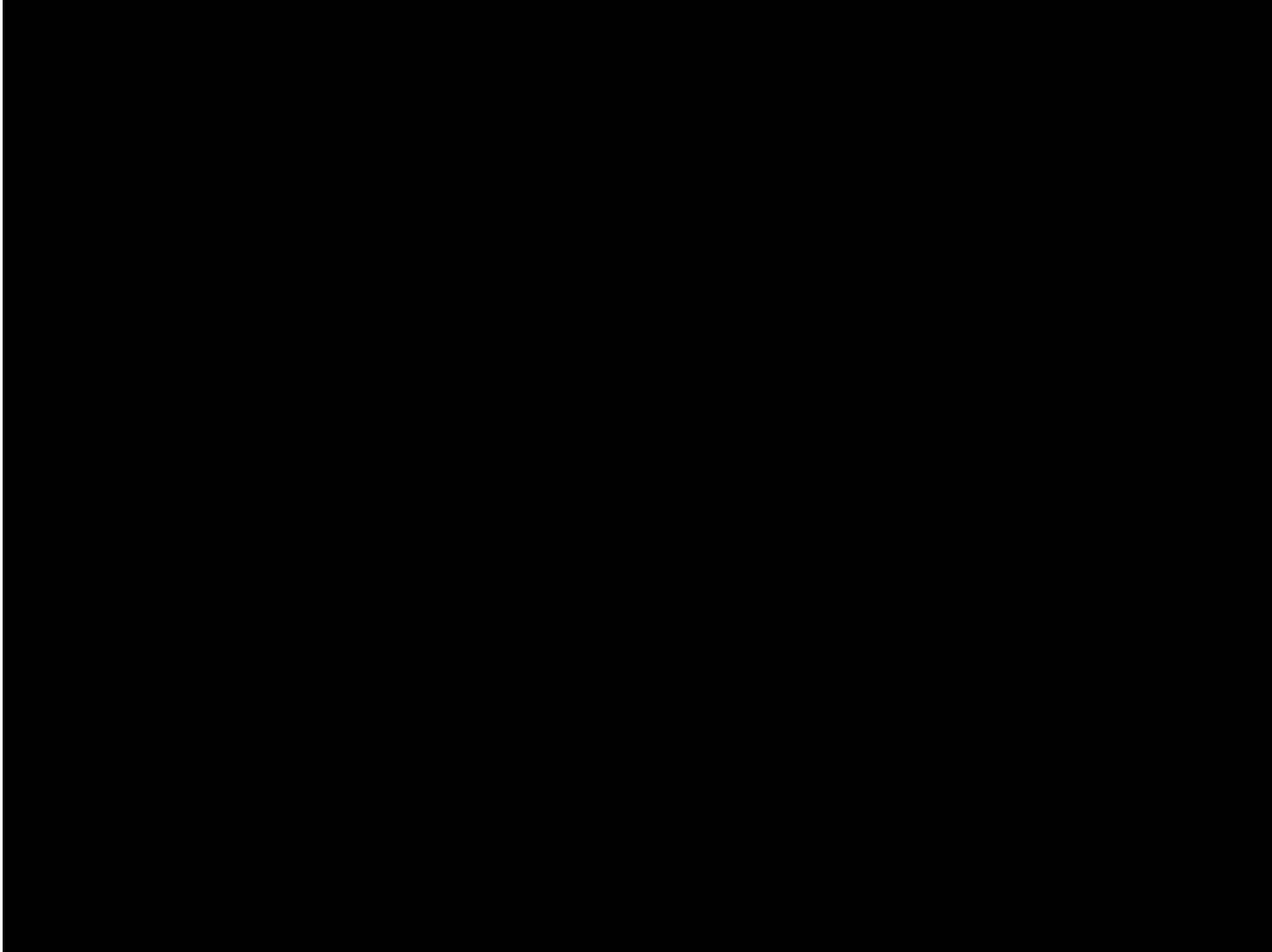
ORIONICE, PPWK, Tele Atlas, Transnavicom, ZENRIN - Terms of Use

**Tags**

artsculture business children cyberactivism  
 development diaspora disaster economics education  
 elections energy entertainment environment ethnically  
 finance food freedomspeech gender  
 governance health history humanitarian  
 humanrights humor ideas indigenous industry  
 internationalrelations internettelecoms labor  
 language law lgbt literature media music photos  
 politics protest racism religion runetechno  
 softwaretools sport technology  
 transparencyandtechnologynetwork travel video warconflict  
 youth

**Results** 671 time 🏠 title 1 2 3 4 5 6 7 8 9 10 11 12 13 14 ▶

Angola: Similarities between Cabinda and East Timor	Zimbabwe: Is it a crime to be white in Zimbabwe?	Ghana: National Media Commission	Africa: A blog to promote African literature	South Africa: Rugby's Part in Transformation	Ecuador: Tungurahua Volcano Erupts and Sends Ash	Nigeria: Exclusive interview with Nigerian soul artist	France: Questions and Controversy about ICC	Oil spill disaster in Singapore	Philippines: Destroying another landmark	Vietnam: Eating "Op la" in Saigon	Vietnam: Report on online censorship	Colombia: Tweeting the May 30 Presidential Elections	Guinea: Waiting for Presidential Elections
Mexico: 165 Mexicans Die Each Day Due to Smoking	Guatemala: Cleaning Up the Ash from Pacaya Volcano	France: A Legal Review of the Burqa Ban Bill	Brazil: Rapper assaulted by Police in Pernambuco	India: Video Giving A Voice To Marginalised Communities	Caucasus: Eurovision Semi-final roundup	Bahrain: On German Freedom	Pakistan: Minorities At Peril	India: Second Class Rail Travel	Pakistan: Attacks in Lahore at Ahmadi Mosque	Algeria: France: Film "Of Gods and Men" Sparks	Bangladesh: FIFA World Cup Memories From The	Zimbabwe: Outlawed newspaper coming back	Eritrea: Exiled editor reunites with family
Caucasus: Boobs, cleavage, and a rare unity in	Nepal: Financial Fraud	Russia: Blogger and Activist Arrested for Viral Video	Iran: Two Bloggers and Student Leader on Hunger	Guatemala: Pacaya Volcano Causes State of	Israel: The Freedom Flotilla - PR Stunt or Humanitarian	Hungary: Facebook v IWW	Hungary: Bloggers' Photo and Video Reports on	Jamaica: Dudus, Security & Seaga	Lebanon: Elections Vs Football	Bahrain: Abu Dhabi's Gold ATMs	Jordan: A Day with a Grave Digger	MENA: 15m Facebook Users	Qatar: The Al Jazeera Initiative for Internet Freedom



# Tufte design principles

Principle of Graphical Integrity

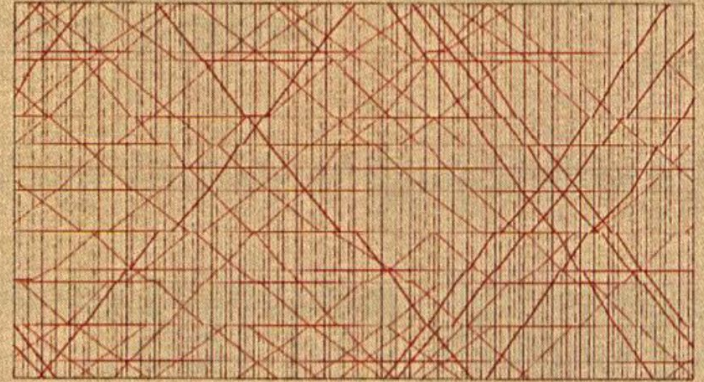
Data-Ink

Chartjunk

Data Density

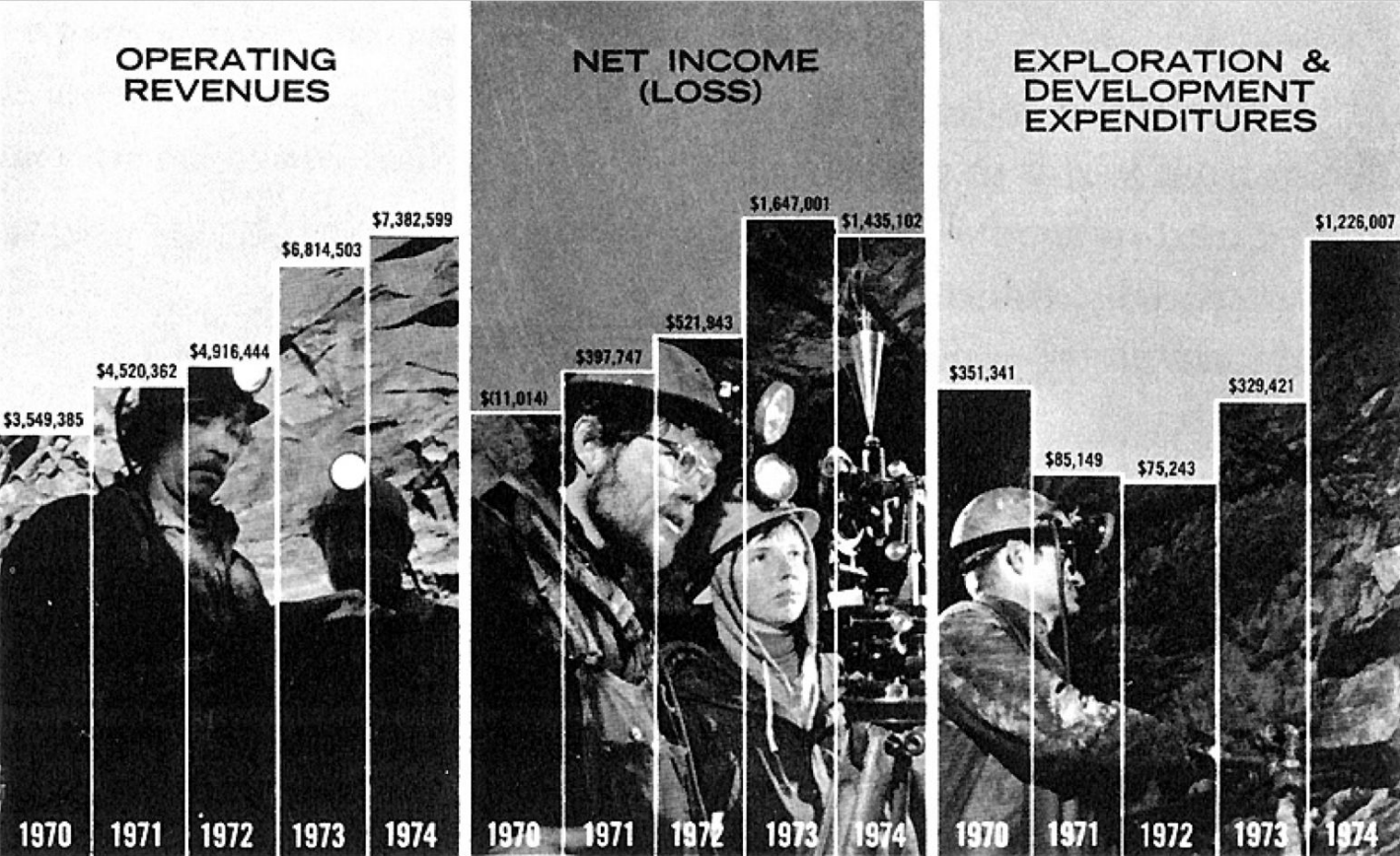
Small Multiples

Principle of Graphical Excellence



## The Visual Display of Quantitative Information

EDWARD R. TUFTE



Principle of Graphical Integrity

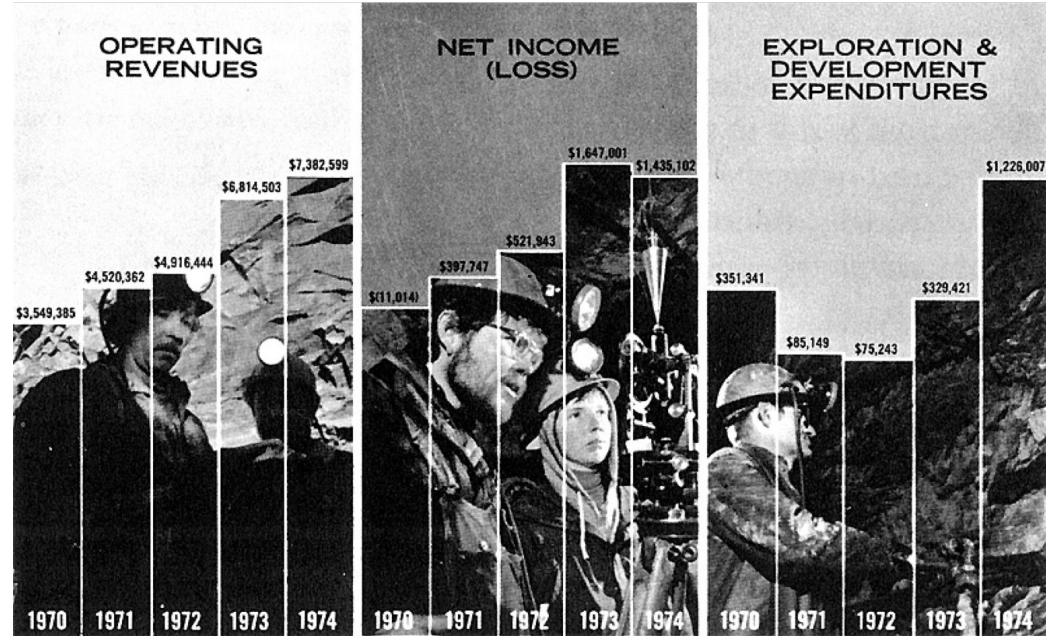
What are the problems of this visualization?

# Principle of Graphical Integrity

Disguised negative income in 1970.

**Different baselines** for three charts make it **incomparable** between charts.

Distracting backgrounds.



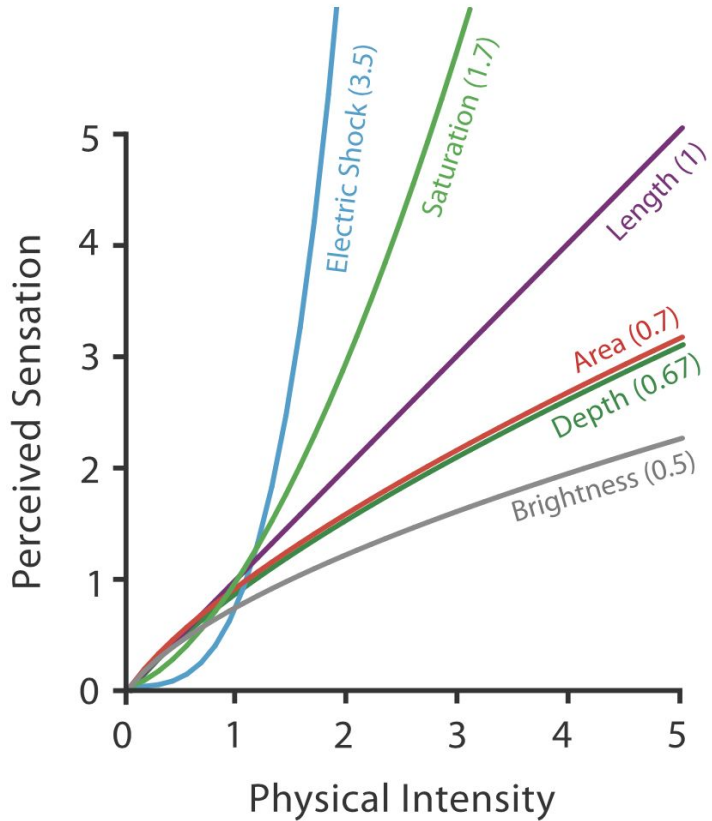
# Principle of Graphical Integrity -- Labeling

**Clear, detailed, and thorough labeling** should be used to defeat graphical distortion and ambiguity.

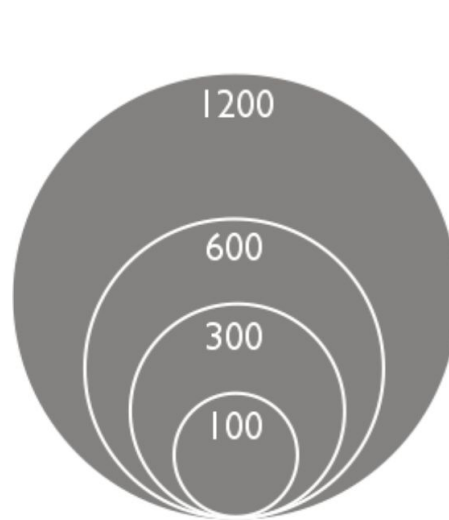
# Principle of Graphical Integrity -- Visual vs. Numerical Scale

The representation of numbers, as **physically** measured on the surface of the graphic itself, should be directly **proportional** to the **numerical** quantities represented.

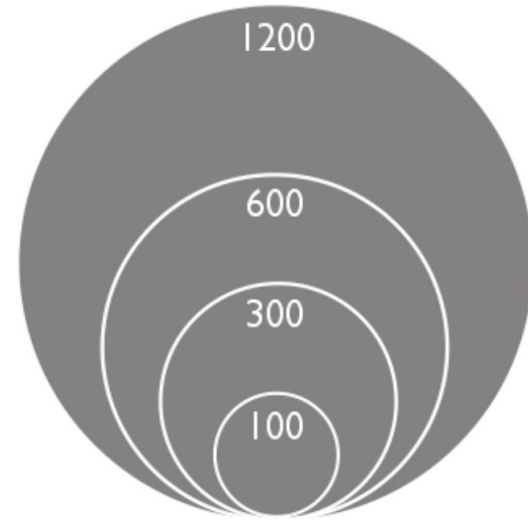
Steven's Psychophysical Power Law:  $S = I^N$



## Counterpoint



Absolute Scaling



Apparent Scaling  
(Flannery's Compensation)

See slides of lecture 2 human perception

# Lie factor

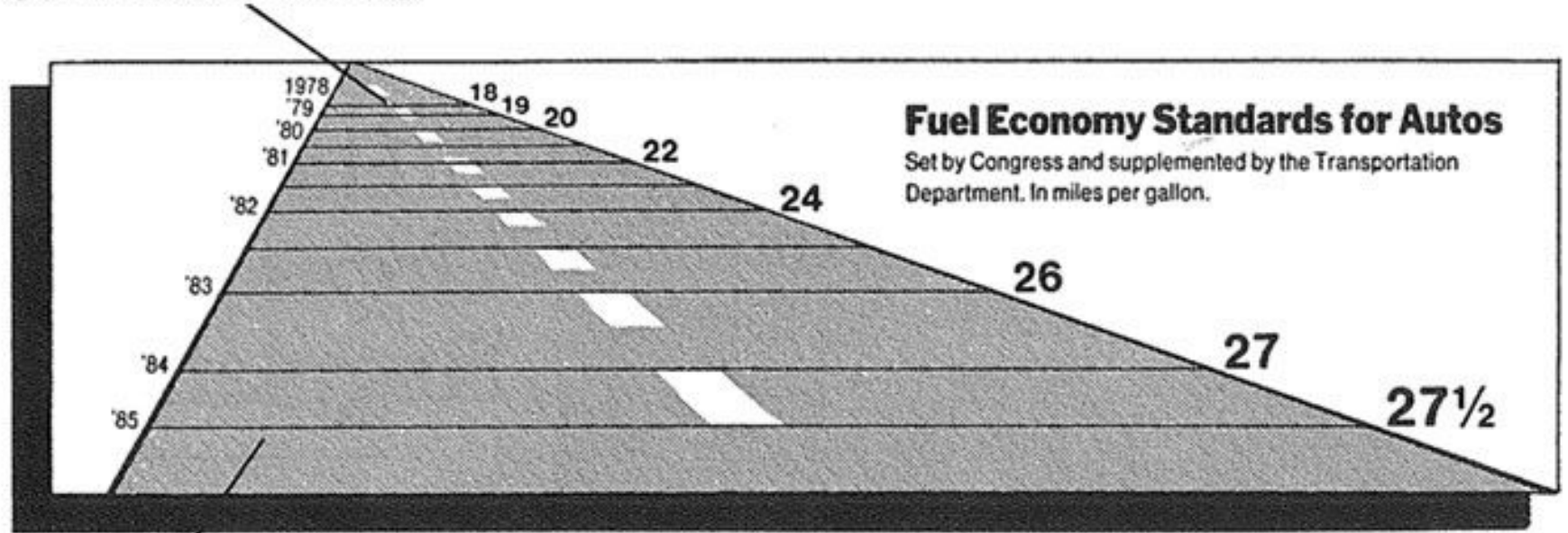
Lie factor = Effect size shown in graphic / Effect size in data.

Lie factor  $\approx 1$ : Truth

Lie factor  $> 1.05$  or  $< 0.95$ : Substantial distortion

# Principle of Graphical Integrity

This line, representing 18 miles per gallon in 1978, is 0.6 inches long.



This line, representing 27.5 miles per gallon in 1985, is 5.3 inches long.

# Principle of Graphical Integrity

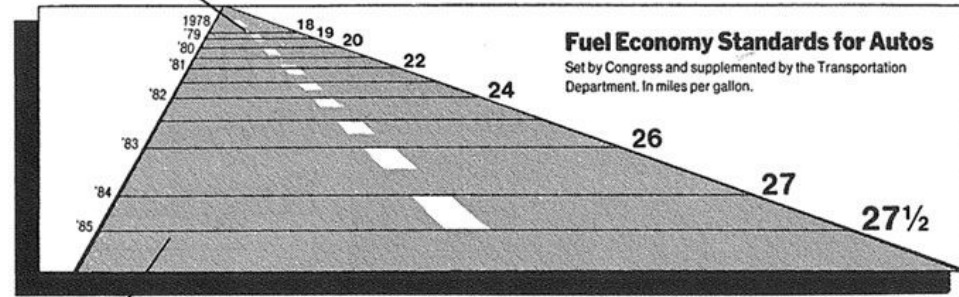
Years showing from future to past.

The width of the road is shrinking due to

- values change,
- perspectives,

no chance of separating the two.

This line, representing 18 miles per gallon in 1978, is 0.6 inches long.



This line, representing 27.5 miles per gallon in 1985, is 5.3 inches long.

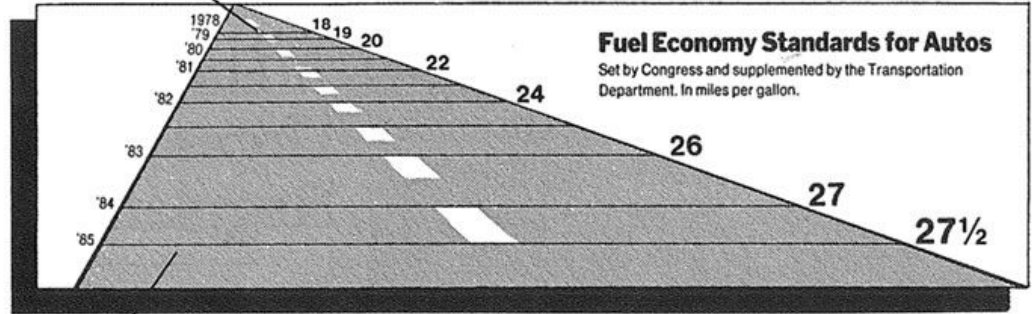
# Principle of Graphical Integrity

Data  $(27.5 - 18.0) / 18.0 = 0.53$

Graphic  $(5.3 - 0.6) / 0.6 = 7.83$

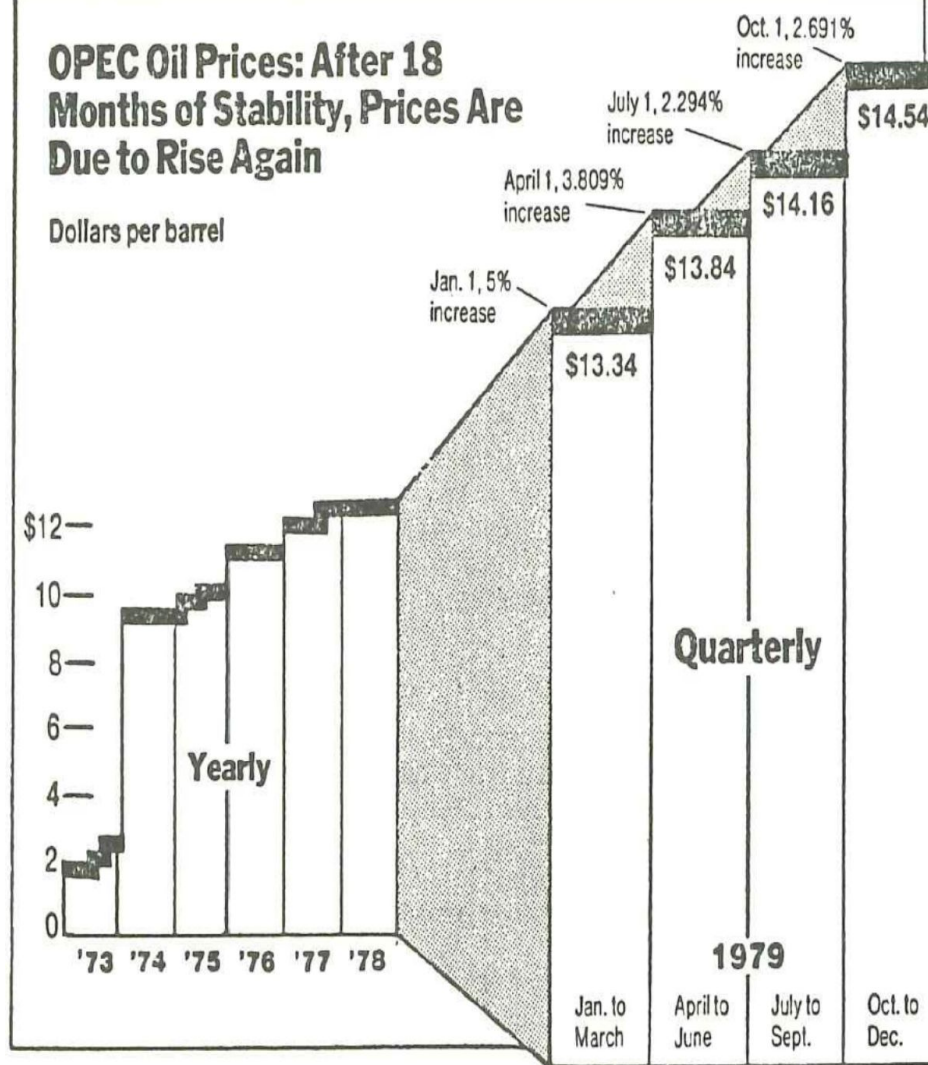
Lie factor =  $7.83 / 0.53 = 14.8$

This line, representing 18 miles per gallon in 1978, is 0.6 inches long.



This line, representing 27.5 miles per gallon in 1985, is 5.3 inches long.

# Principle of Graphical Integrity

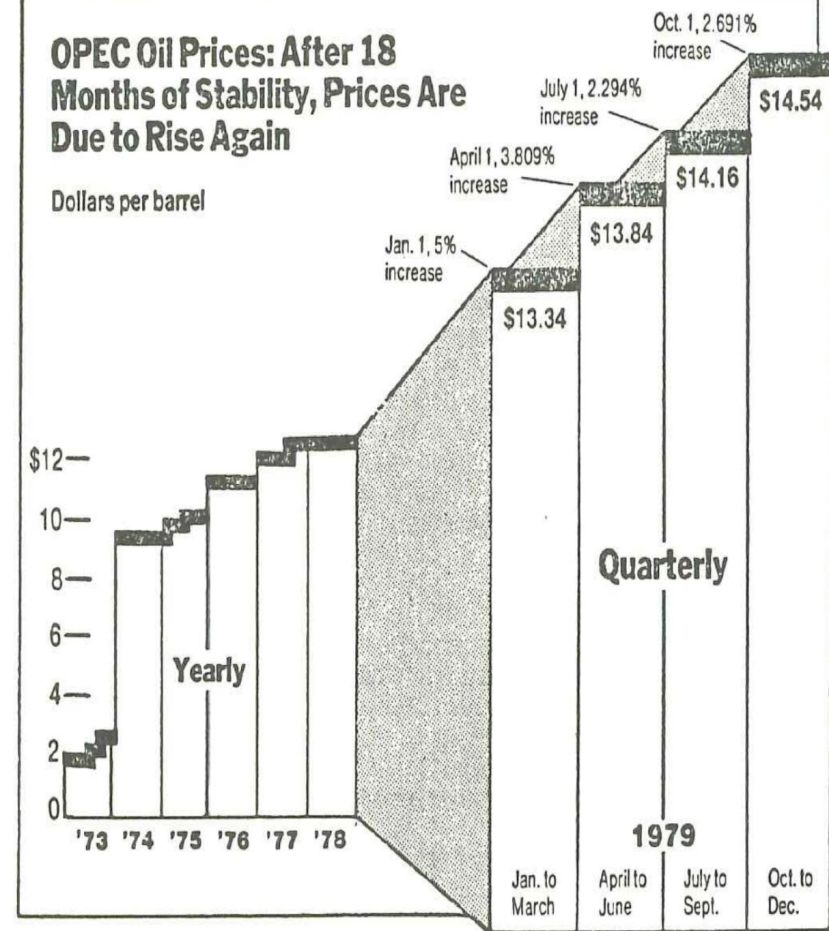


# Principle of Graphical Integrity

Left: \$10 for one year is 0.31 square inches.

Right: \$10 for one year is 4.69 square inches.

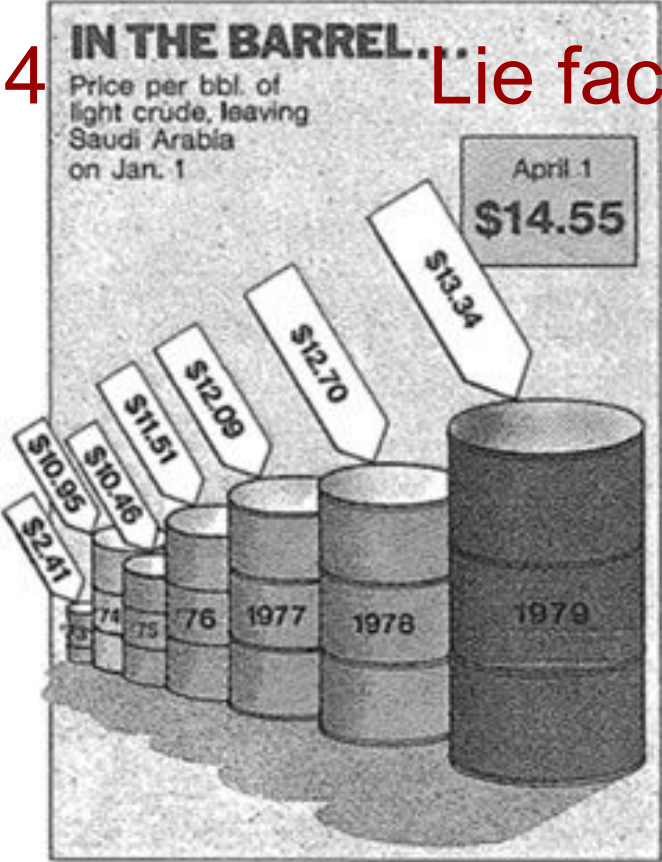
Lie factor =  $4.69 / 0.31 = 15.1$



## Principle of Graphical Integrity

**Variation: Show data variation, not design variation.**

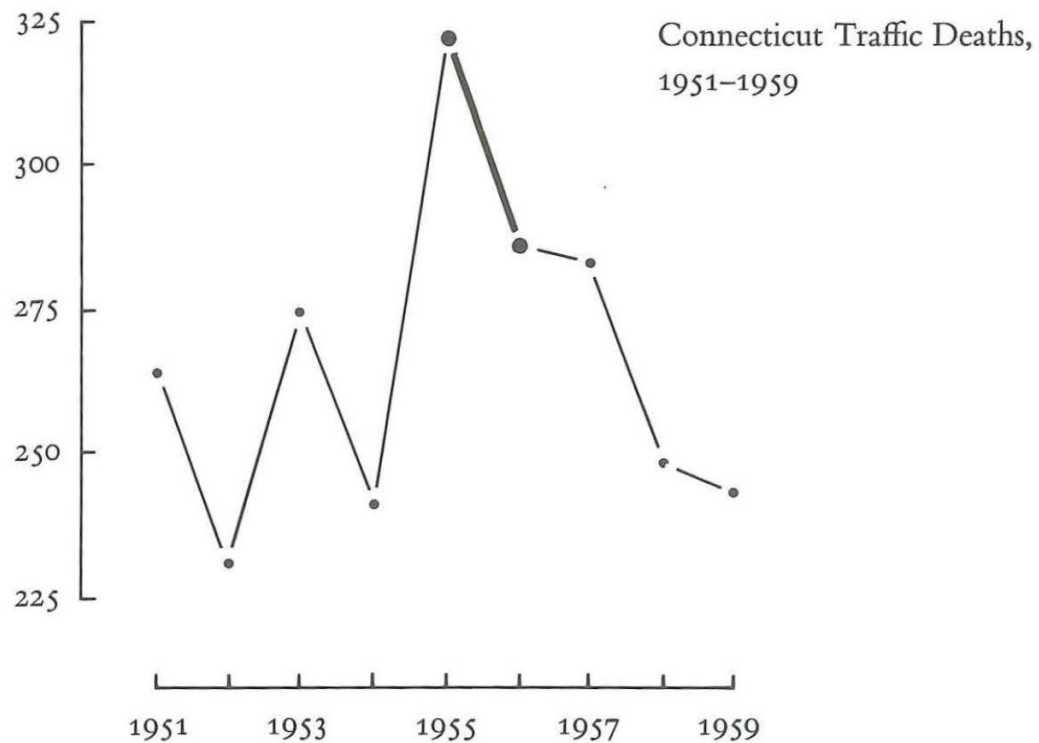
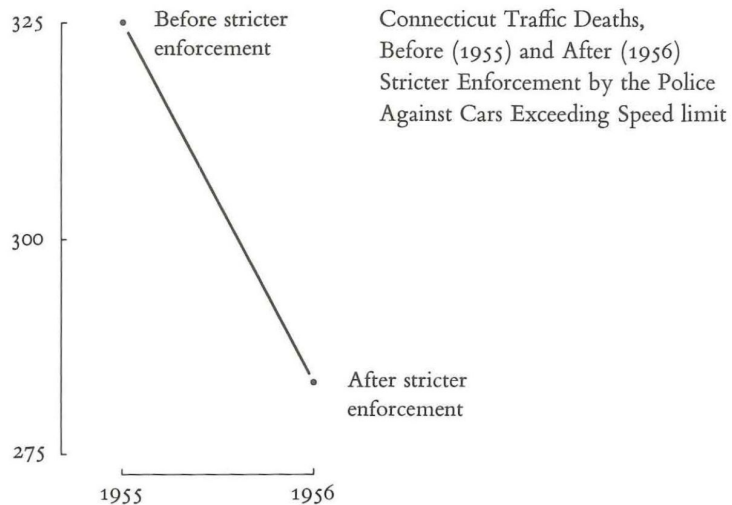
# Principle of Graphical Integrity



## Principle of Graphical Integrity

Visual vs. data dimensions: The number of information-carrying (**variable**) **dimensions** depicted should not exceed **the number of dimensions** in the data.

## Context: Graphics must not quote data out of context.



# Principle of Graphical Integrity

**Visual vs. numerical scale:** The representation of numbers, as physically measured on the surface of the graphic itself, should be directly proportional to the numerical quantities represented.

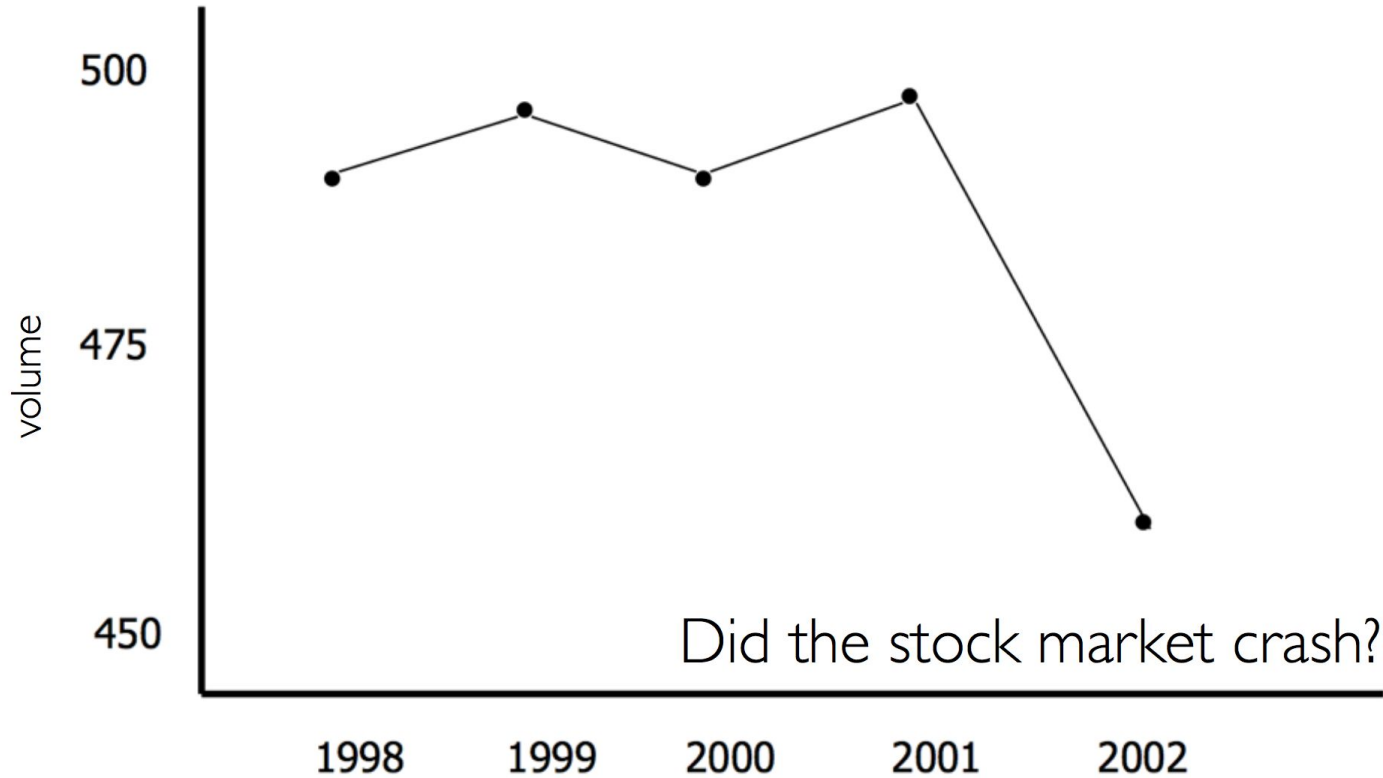
**Labeling:** Clear, detailed, and thorough labeling should be used to defeat graphical distortion and ambiguity.

**Variation:** Show data variation, not design variation.

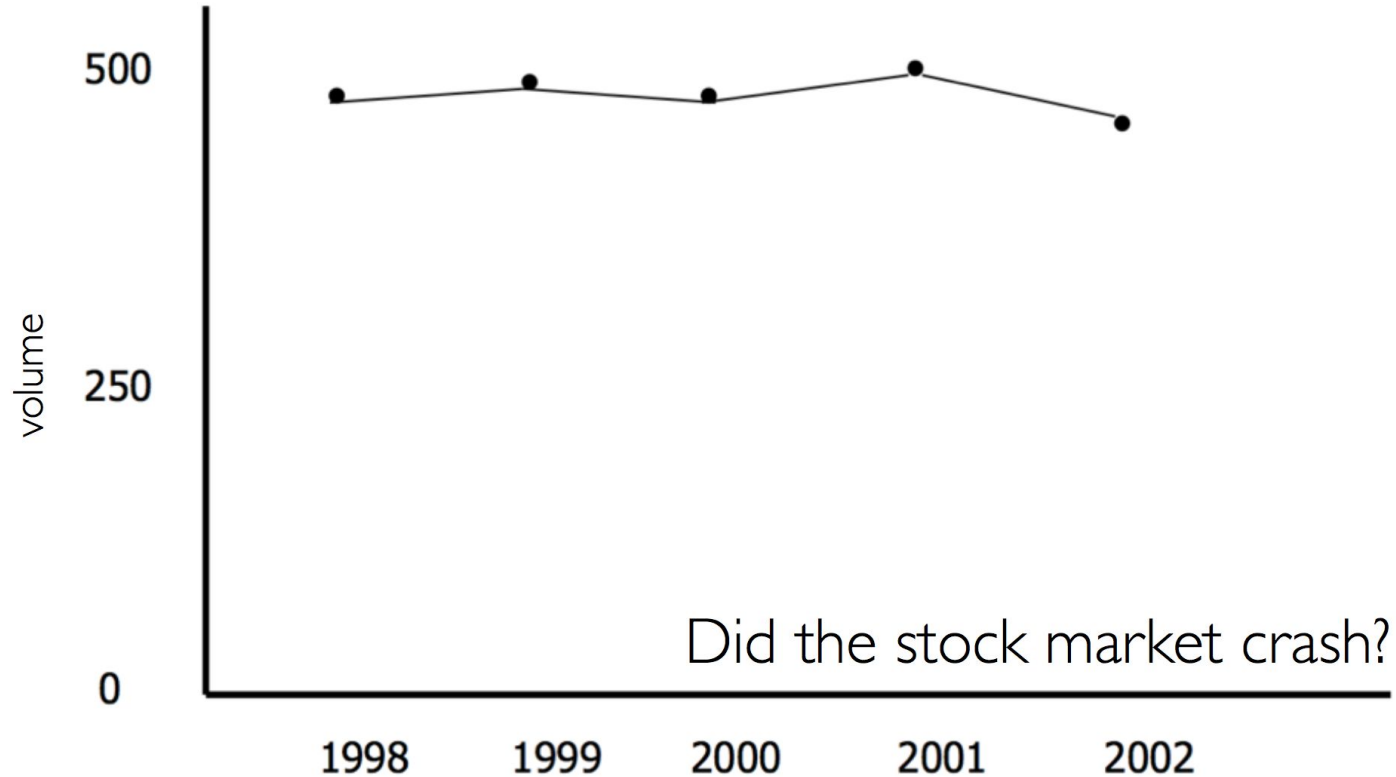
**Visual vs. data dimensions:** The number of information-carrying (variable) dimensions depicted should not exceed the number of dimensions in the data.

**Context:** Graphics must not quote data out of context.

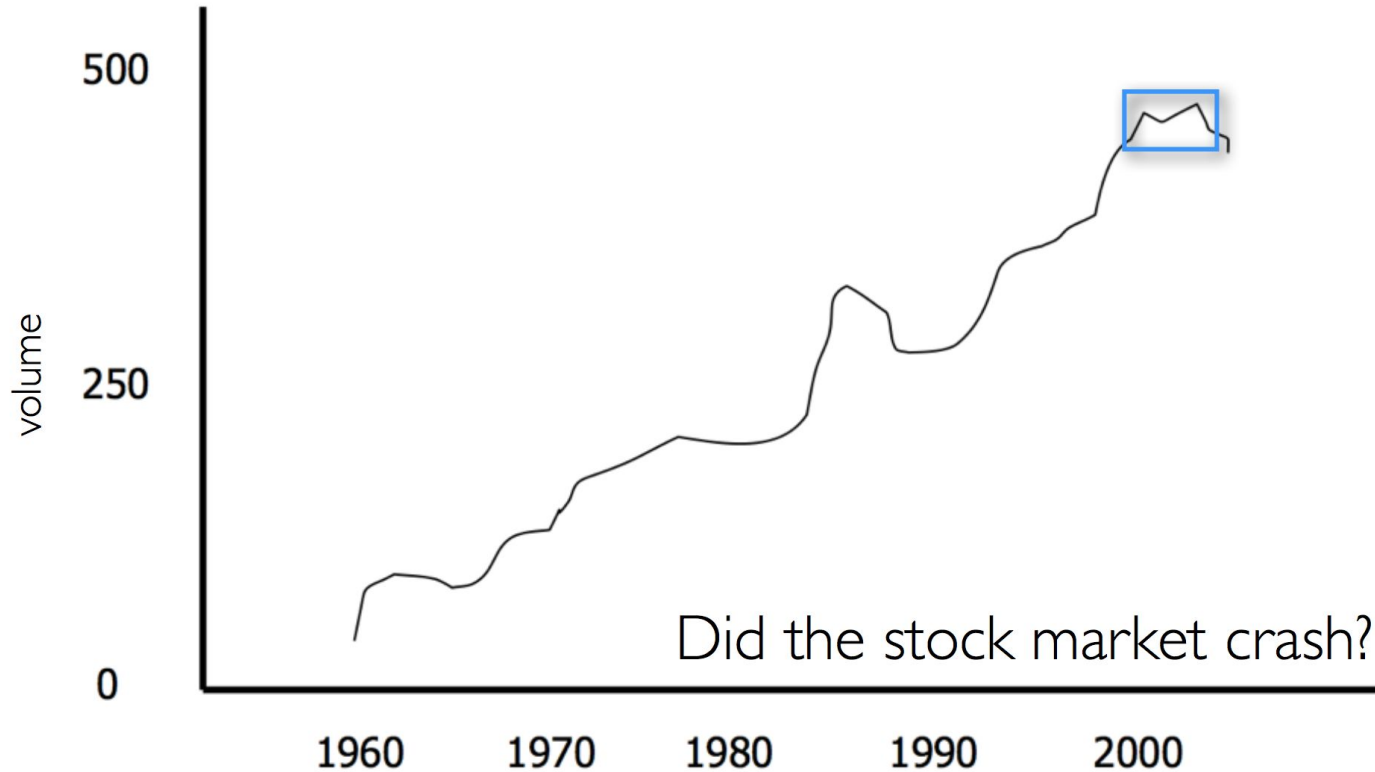
# Principle of Graphical Integrity



# Principle of Graphical Integrity -- Scale



# Principle of Graphical Integrity -- Context



# Data-Ink

Data-ink ratio = data-ink / total ink used to print the graphic

= 1.0 - proportion of a graphic that can be erased without loss of data-information

# Data-Ink

Above all else show the data

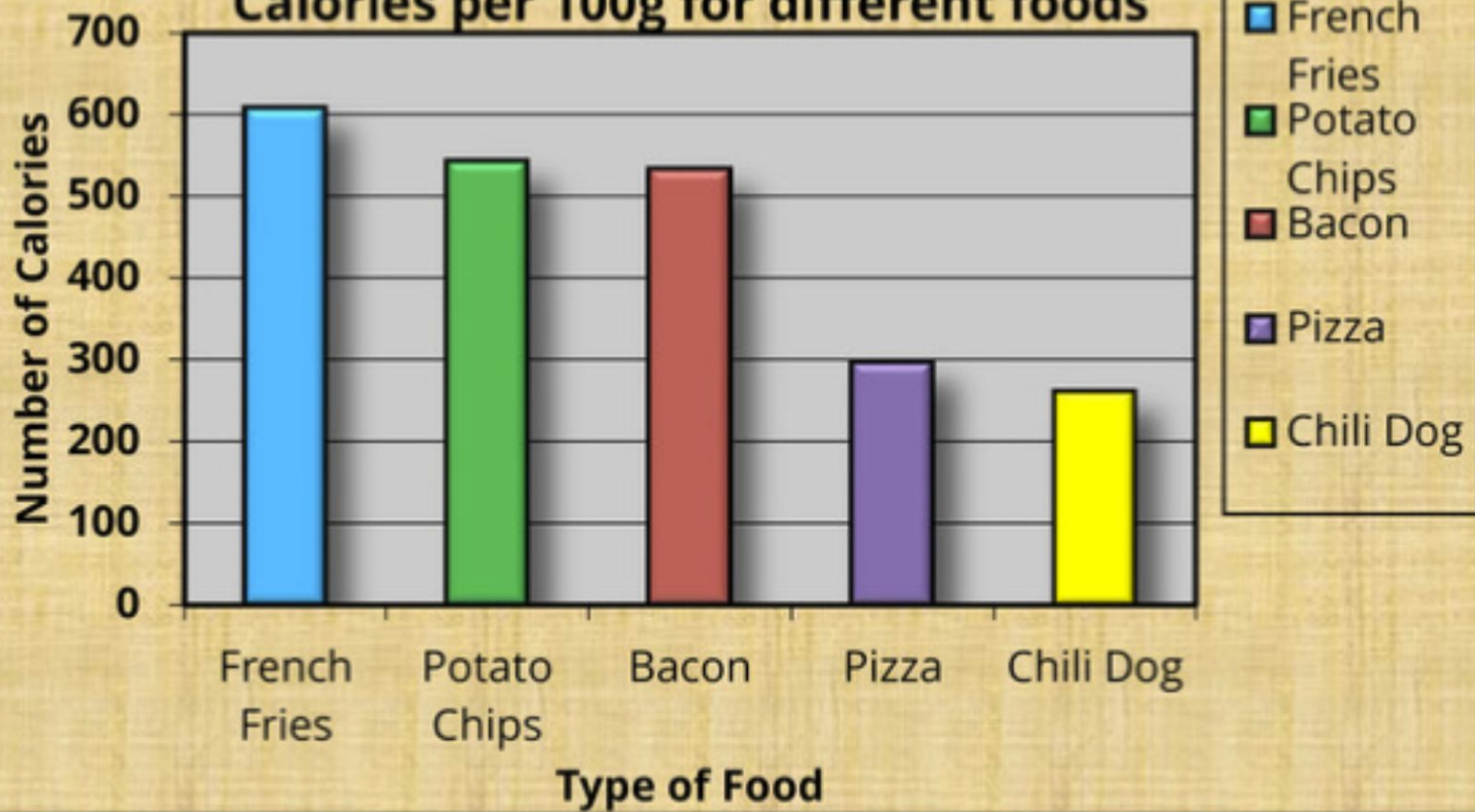
Maximize the data-ink ratio, within reason

Erase non-data-ink, within reason

Erase redundant data-ink, within reason

Revise and edit

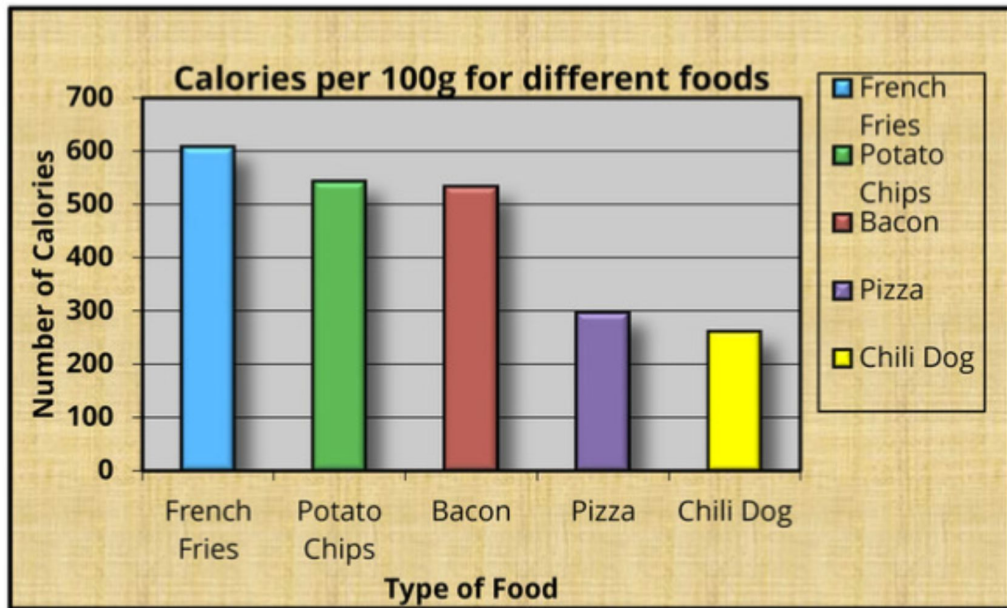
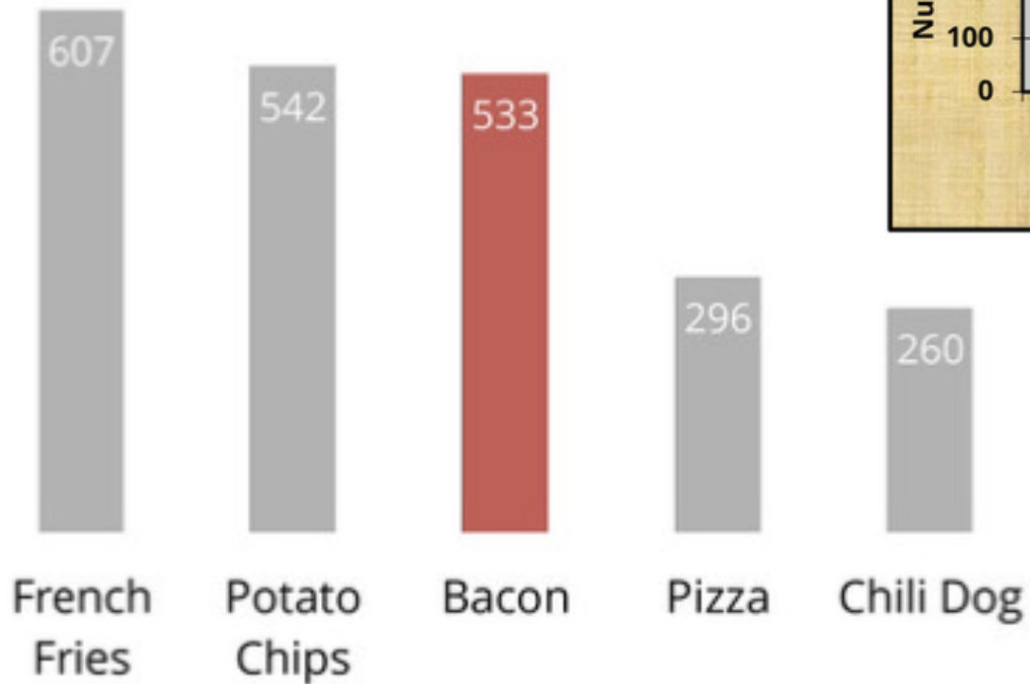
Calories per 100g for different foods

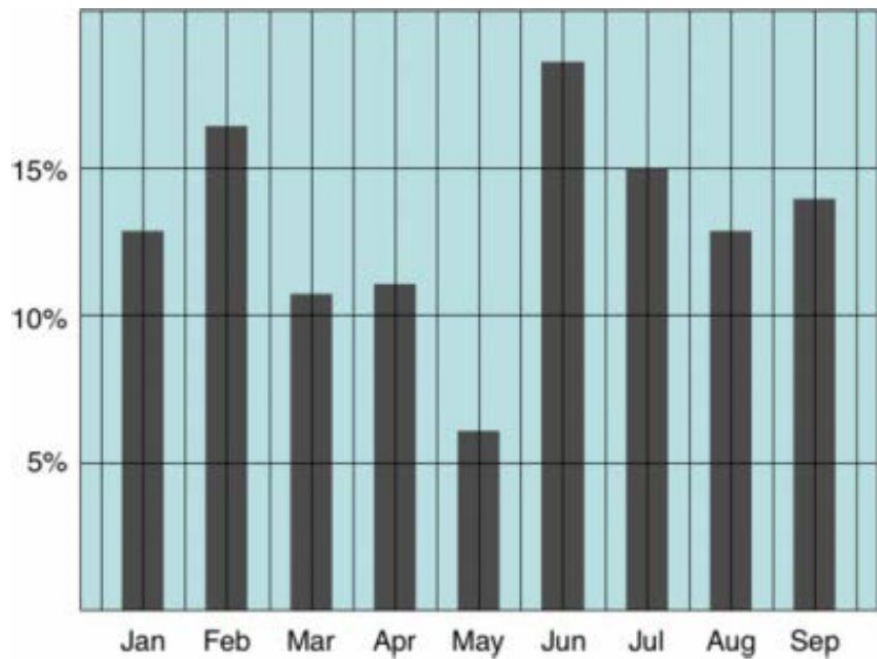


How to increase the data-ink ratio of this visualization?

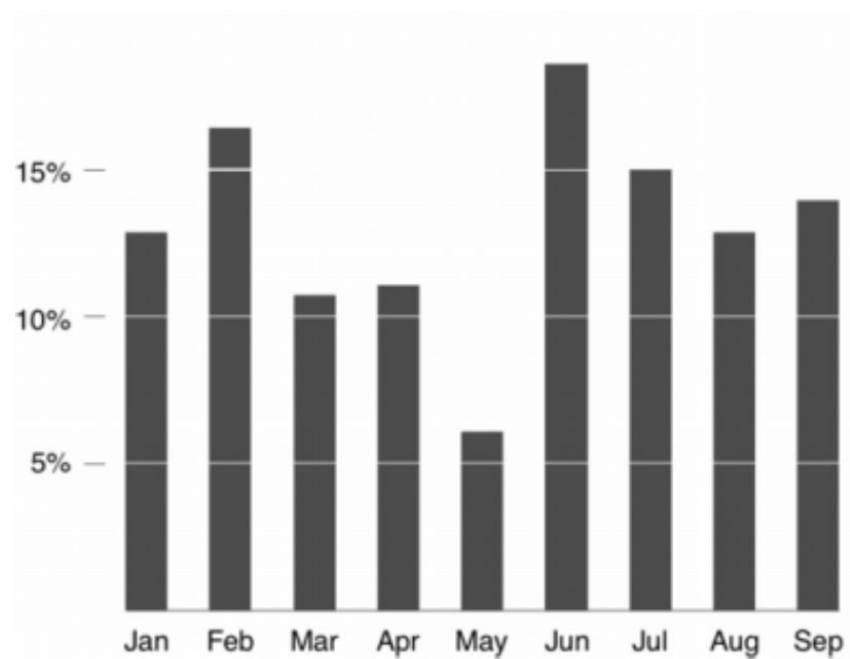
**Remove**  
to improve  
(the **data-ink** ratio)

## Calories per 100g



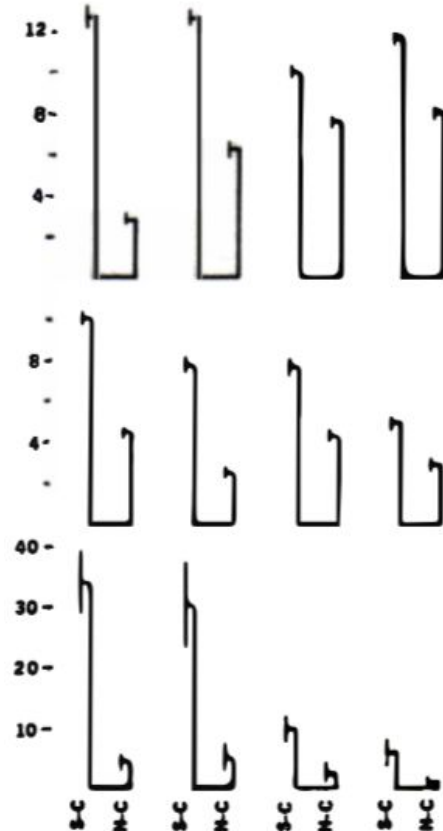
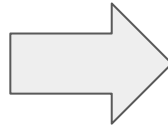
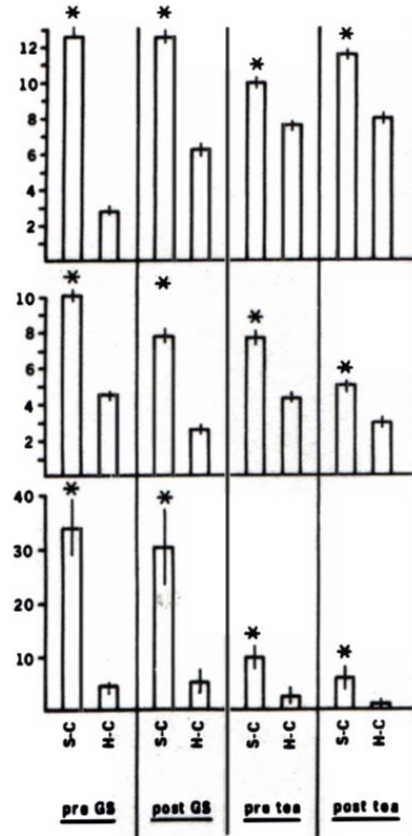


**Low Data Ink (BAD)**

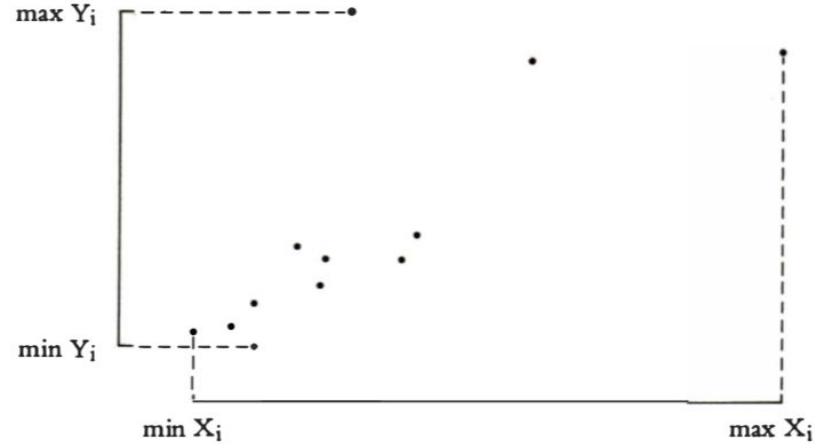
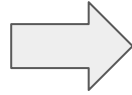


**High Data Ink (GOOD)**

# Application of the data-ink principle



# Application of the data-ink principle

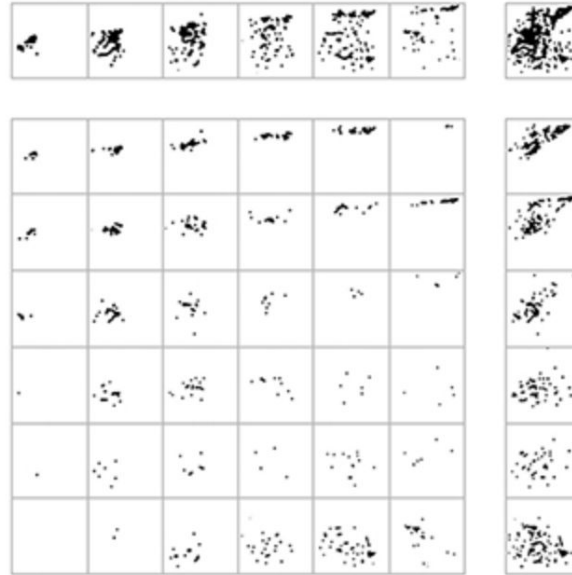
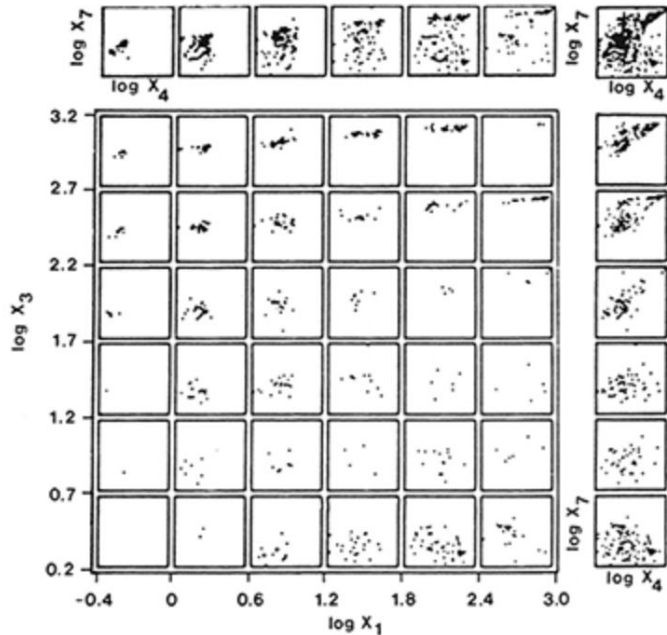




# Chartjunk -- The grid

The grid should be muted relative to the data.  
Avoid doubled grid lines.

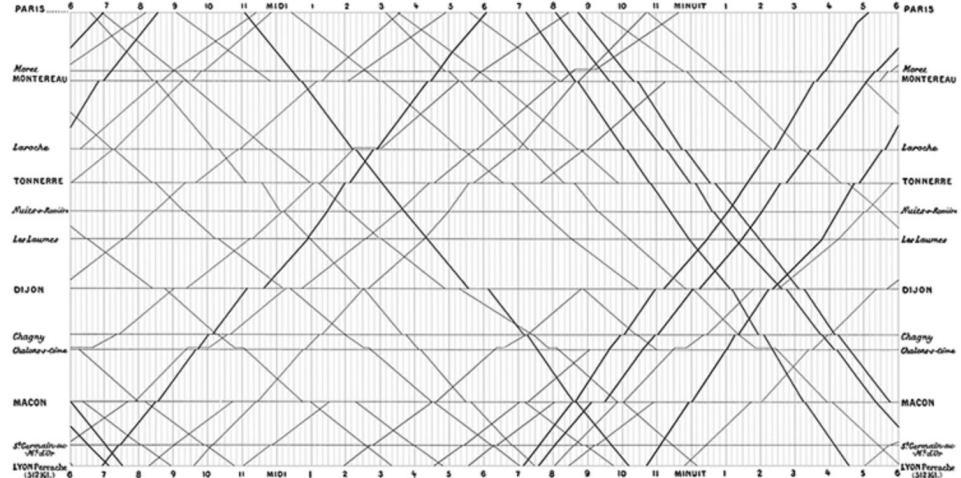
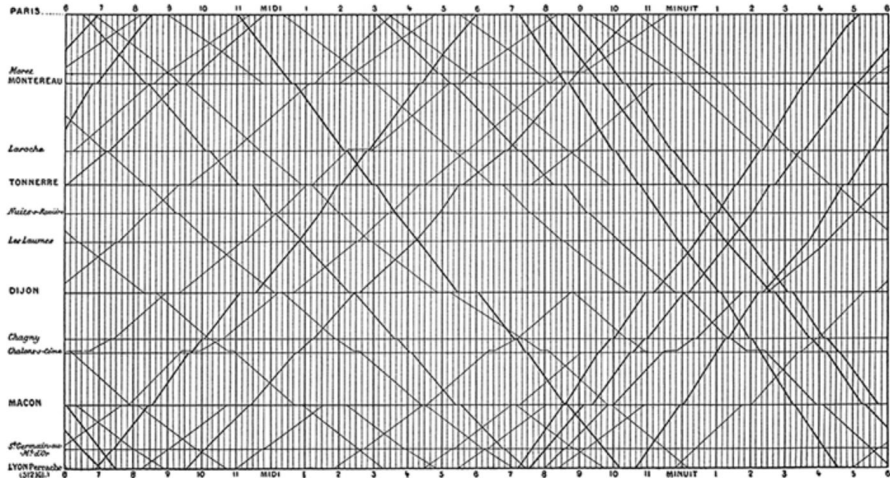
MULTIWINDOW PLOT OF PARTICLE PHYSICS MOMENTUM DATA



# Chartjunk -- The grid

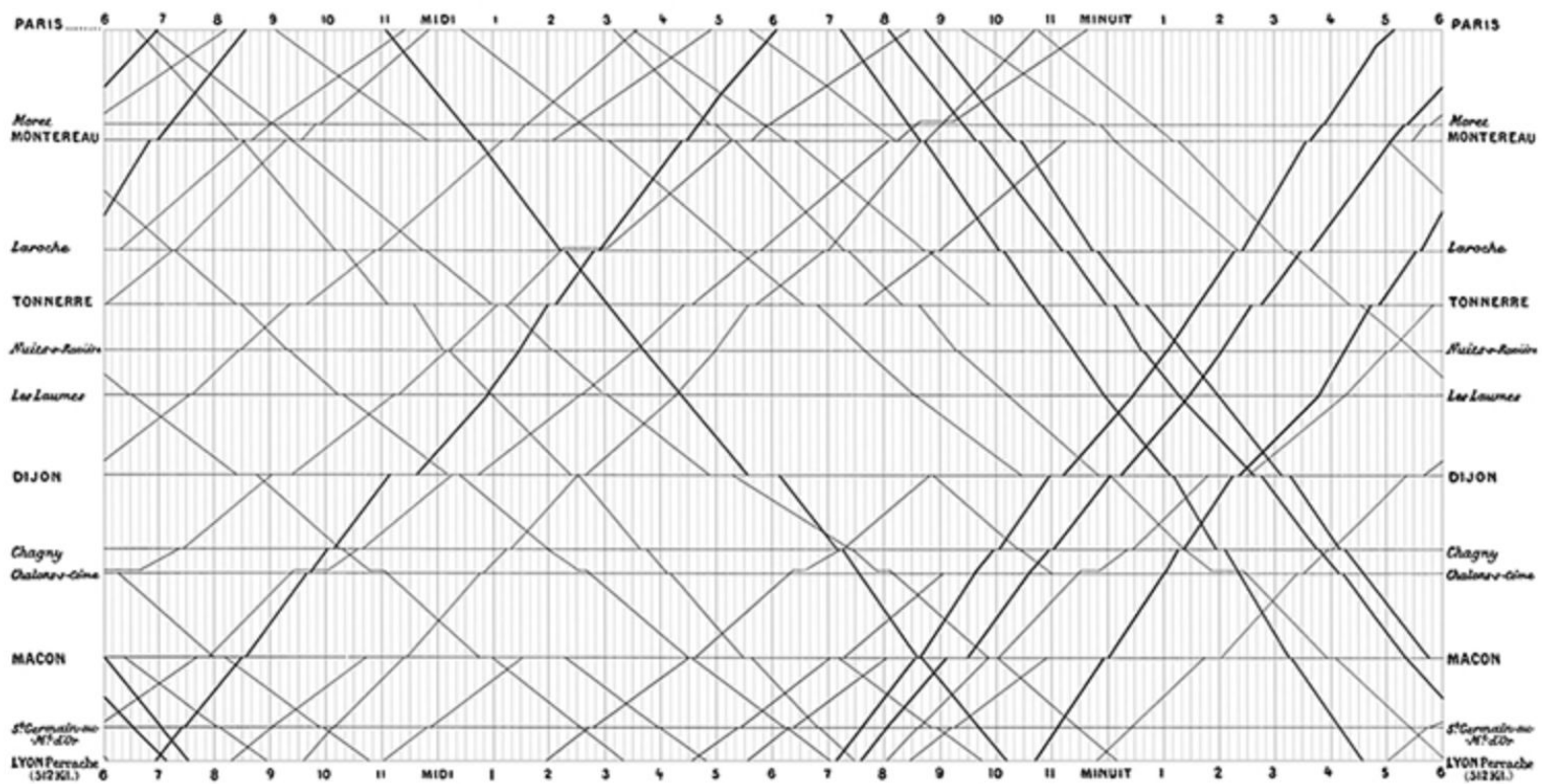
A grid can help in reading and interpolating.

A gray grid can promote more accurate data reconstruction than a dark grid.



Train schedule

What information do you get out of the chart?



**Arrivals and departures** from a station are located along the horizontal line. Stations are separated in **proportion** to their **actual distances**. **Length of a stop** at a station is indicated by **the length of the horizontal line**. The **slope** of the line reflects the **speed** of the train.

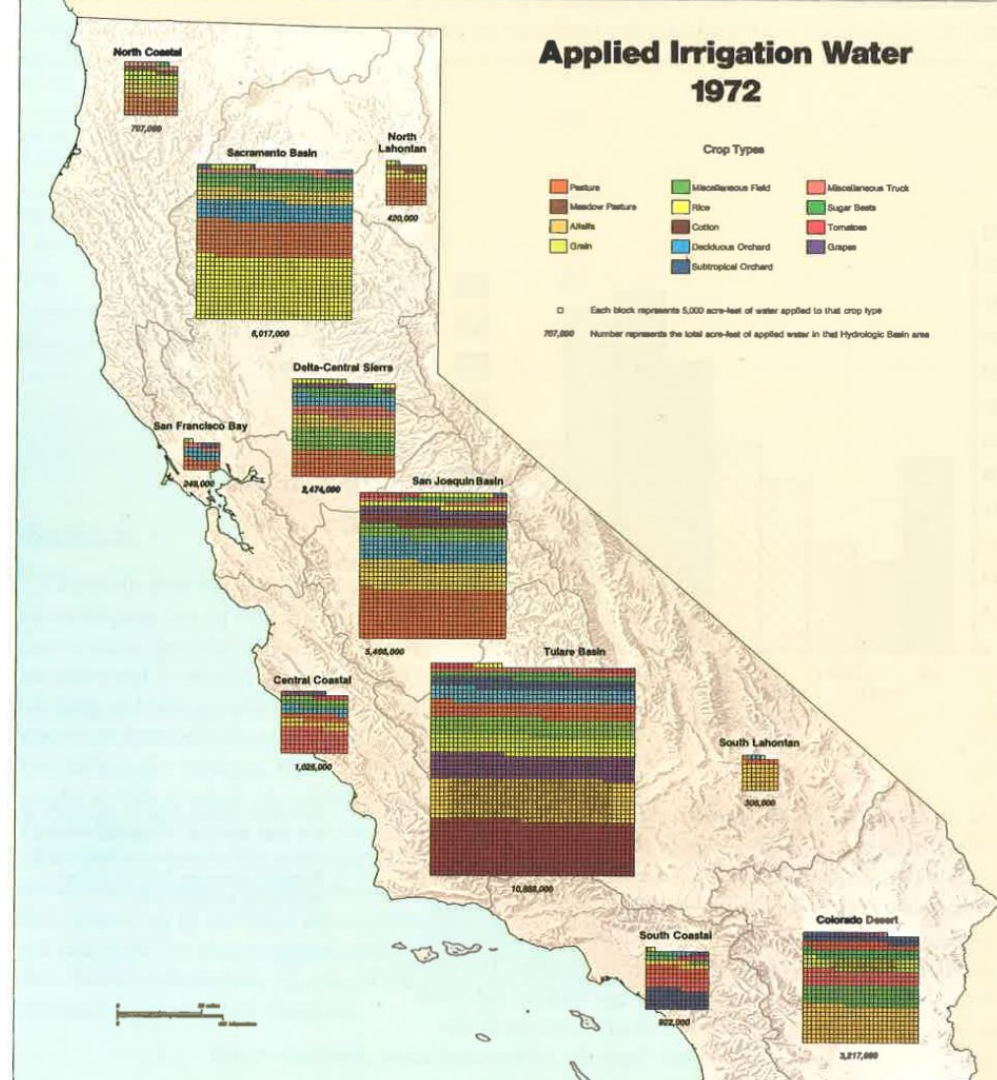
# Chartjunk -- The duck

Chart elements that added no value whatsoever, other than to distract or entertain the viewer.



# Chartjunk -- The duck

How can the data-ink be made more clear eliminating the need for the legend?

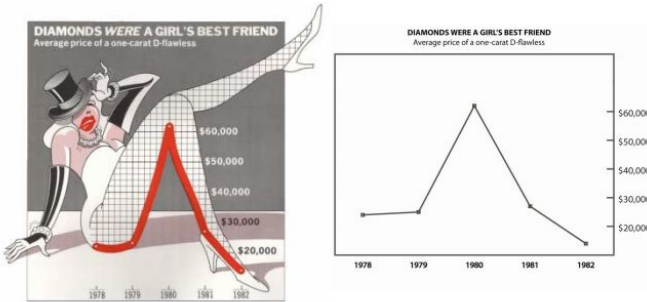


# Useful Junk? The Effects of Visual Embellishment on Comprehension and Memorability of Charts

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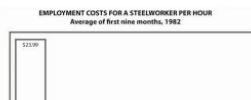
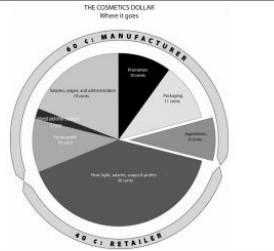
**Significantly better recall of embellished charts than plain charts after a two-to-three week gap.**



Despite these minimalist guidelines, many designers include a wide variety of visual embellishments in their charts, from small decorations to large images and visual backgrounds. One well-known proponent of visual embellishment in charts is the graphic artist Nigel Holmes, whose work regularly incorporates strong visual imagery into the fabric of the chart [7] (e.g., Figure 1).

## MONSTROUS COSTS

Total House and Senate campaign expenditures, in millions

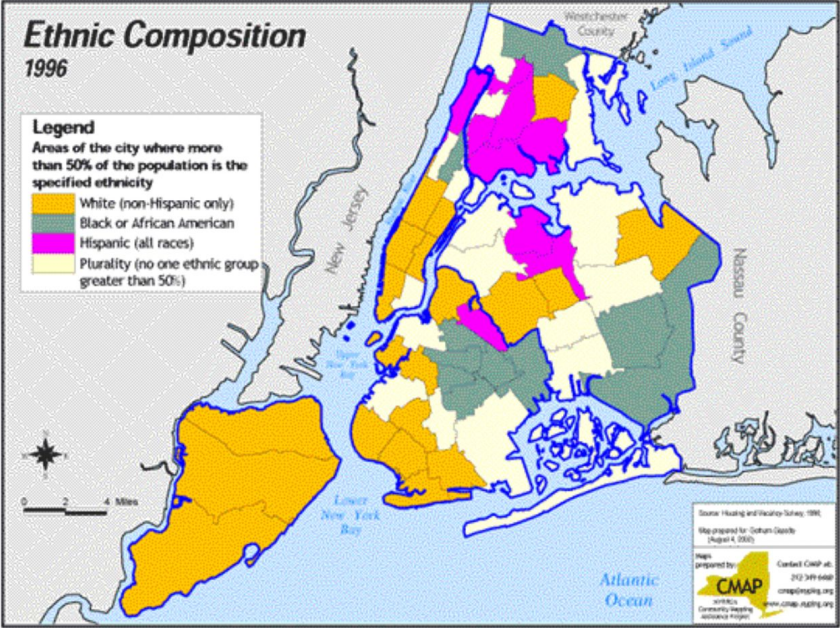


Chartjunk -- Counterpoints



# Data density

Data density of a graphic = number of entries in data matrix / area of data graphic



Low Data Density (BAD)

High Data Density (GOOD)

# Data density

## **Maximize**

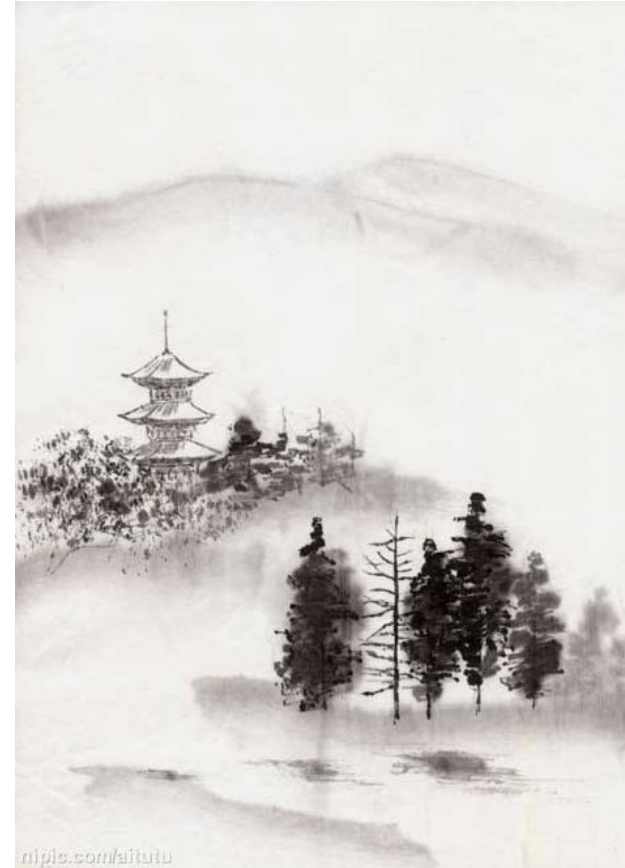
the size of the data matrix;  
data density,  
within reason.

Graphics can be shrunk way down.

# Data density -- Critiques

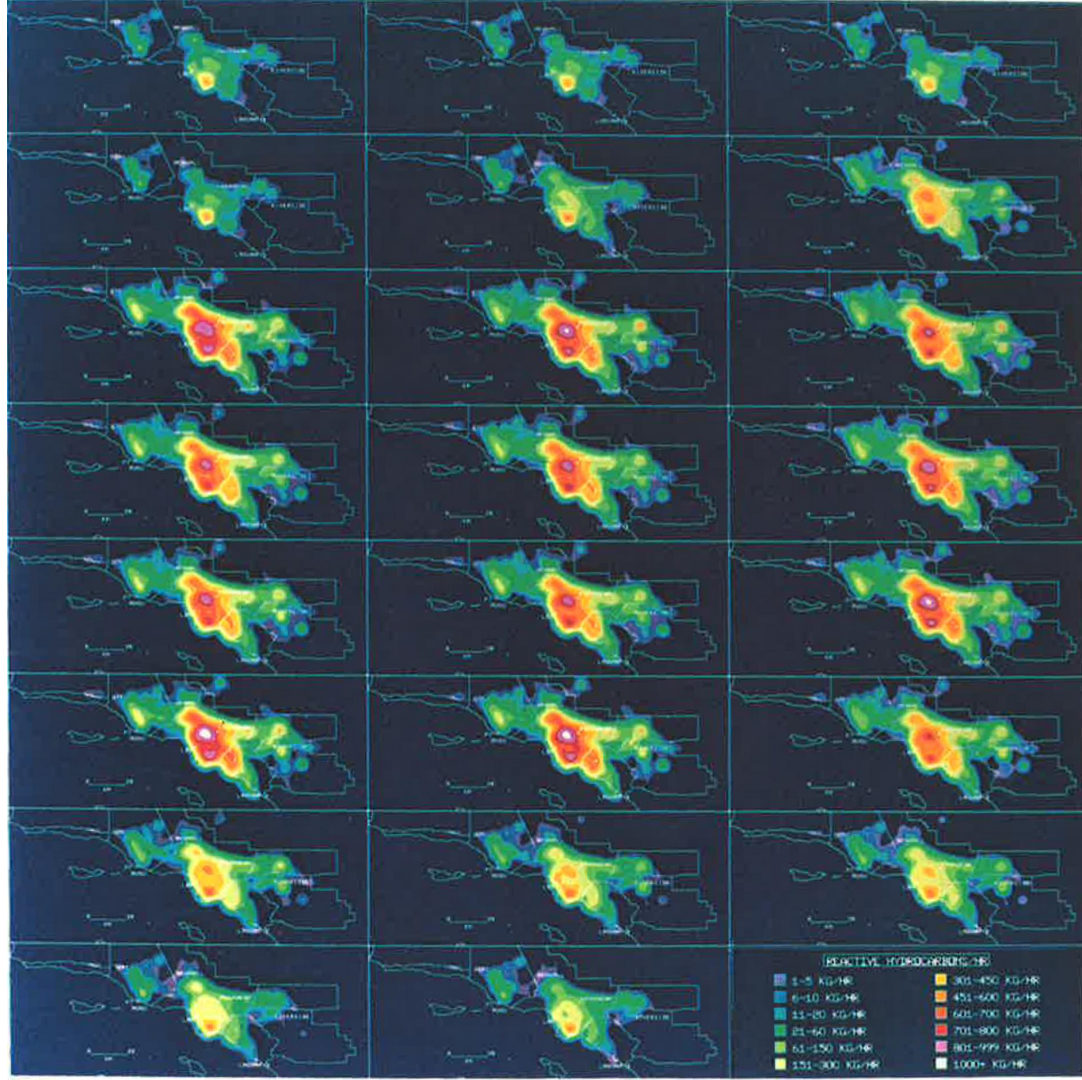
White space thought to contribute to good visual design.

Tufte's book itself has lots of white space.



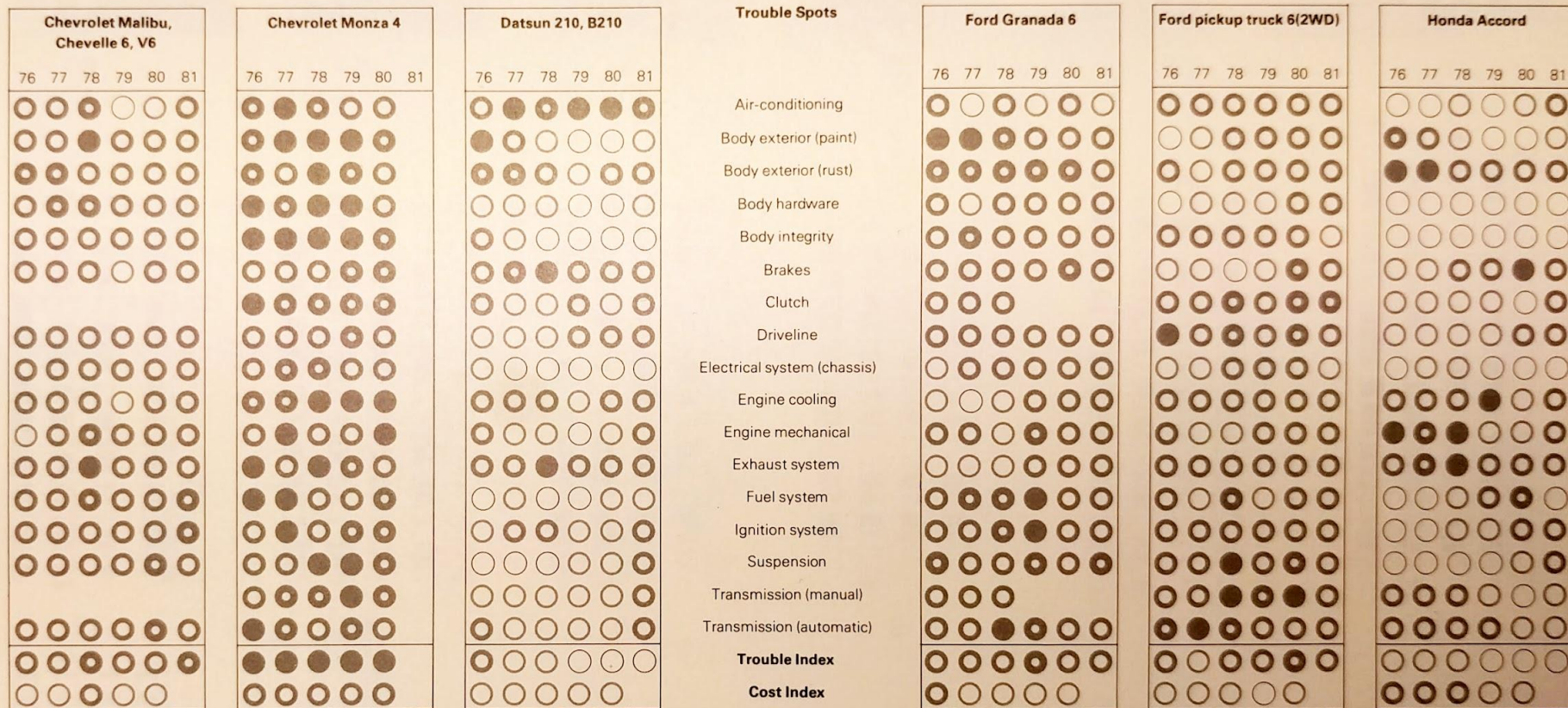
# Small multiples

Repeated application of the Shrink principle.



○ = Much better than average   ○ = Better than average   ○ = Average   ○ = Worse than average   ● = Much worse than average

# Small multiples



# Small multiples

Well designed small multiples are

Comparative;

Multivariate;

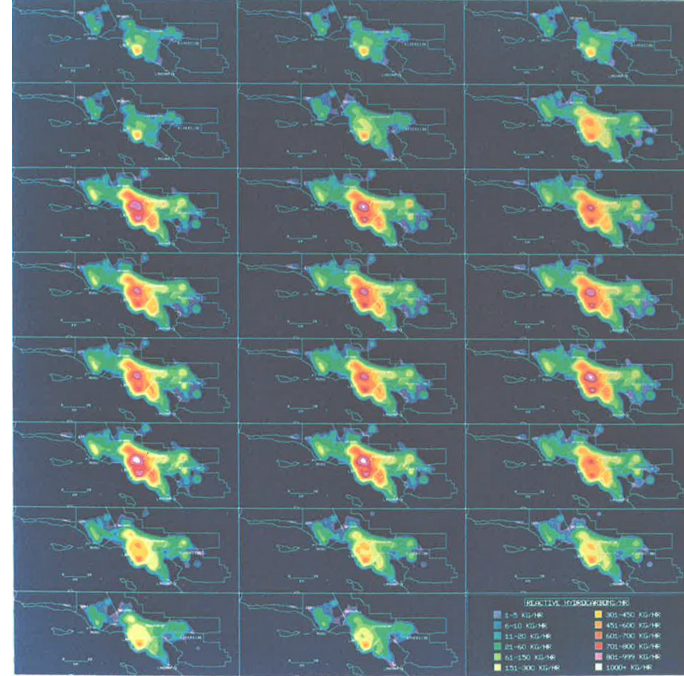
Shrunken, highly-dense graphics;

Usually based on a large data matrix;

Drawn almost entirely with data-ink;

Efficient in interpretation;

Often narrative in content, showing shifts in the relationship between variables as the index variable changes.



# Principle of Graphical Excellence

Communicate **complex** ideas with **clarity**, **precision**, and **efficiency**.

Give the viewer

the **greatest** number of ideas

in the **shortest** time

with the **least** ink

in the **smallest** space.

**Tell the truth** about the data.

# Recap

The L.A.T.C.H principle -- Methods of organization.

Tufte design principles

Principle of Graphical Integrity

Data-Ink

Chartjunk

Data Density

Small Multiples

Principle of Graphical Excellence

R E C A P