

Evaluation Principles

Visual Display of Quantitative Information

Resources

- **Envisioning Information**

by Edward R. Tufte, Graphics Press, 1990

- **Visual Explanations**

by Edward R. Tufte, Graphics Press, 1997

- **The Visual Display of Quantitative Information** ←

by Edward R. Tufte, Graphics Press, 2001

GRAPHICAL EXCELLENCE

VDQI Chapter 1

Graphics **reveal** data.

I		II		III		IV	
X	Y	X	Y	X	Y	X	Y
10.0	8.04	10.0	9.14	10.0	7.46	8.0	6.58
8.0	6.95	8.0	8.14	8.0	6.77	8.0	5.76
13.0	7.58	13.0	8.74	13.0	12.74	8.0	7.71
9.0	8.81	9.0	8.77	9.0	7.11	8.0	8.84
11.0	8.33	11.0	9.26	11.0	7.81	8.0	8.47
14.0	9.96	14.0	8.10	14.0	8.84	8.0	7.04
6.0	7.24	6.0	6.13	6.0	6.08	8.0	5.25
4.0	4.26	4.0	3.10	4.0	5.39	19.0	12.50
12.0	10.84	12.0	9.13	12.0	8.15	8.0	5.56
7.0	4.82	7.0	7.26	7.0	6.42	8.0	7.91
5.0	5.68	5.0	4.74	5.0	5.73	8.0	6.89



$$N = 11$$

$$\text{mean of } X\text{'s} = 9.0$$

$$\text{mean of } Y\text{'s} = 7.5$$

$$\text{equation of regression line: } Y = 3 + 0.5X$$

$$\text{standard error of estimate of slope} = 0.118$$

$$t = 4.24$$

$$\text{sum of squares } X - \bar{X} = 110.0$$

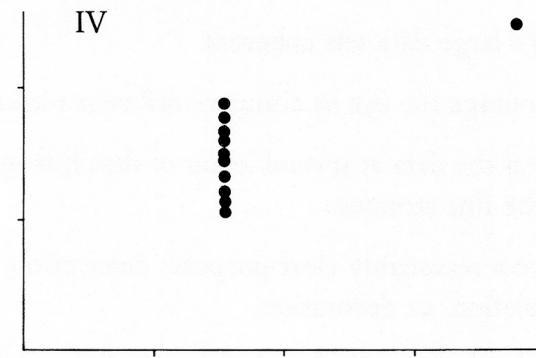
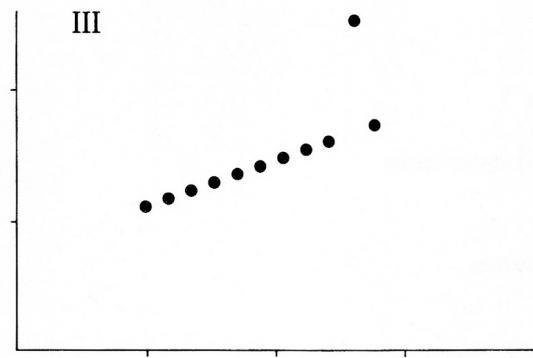
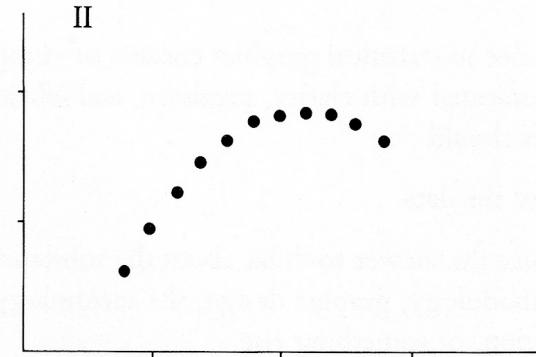
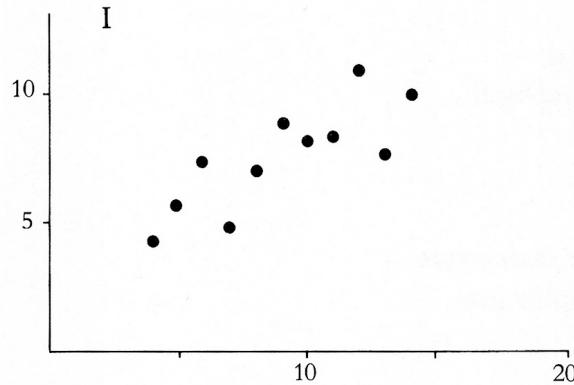
$$\text{regression sum of squares} = 27.50$$

$$\text{residual sum of squares of } Y = 13.75$$

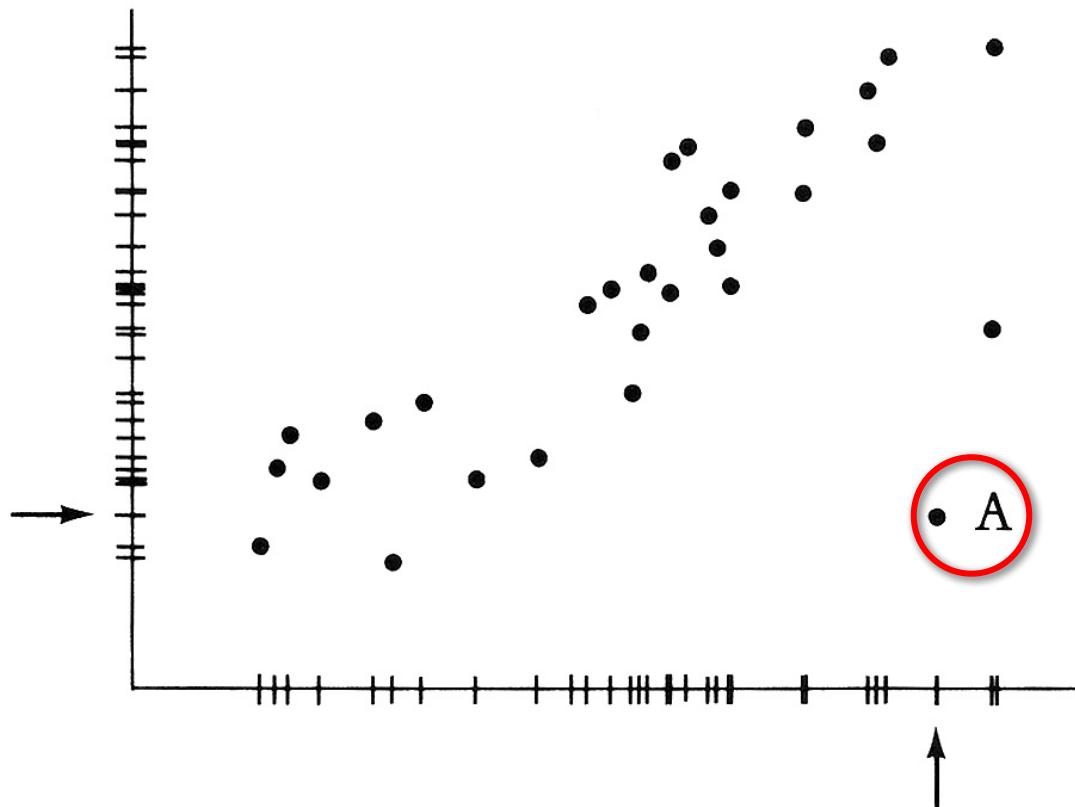
$$\text{correlation coefficient} = .82$$

$$r^2 = .67$$

VDQI Example (p13)



VDQI Example (p13)



VDQI Example (p14)

Graphical Excellence

- Avoid distorting the data
- Reveal data at different levels of detail
- Present many numbers in a small space 
- Encourage comparison
- Encourage viewers to think about the data, not graphic design, etc.

FRANKED MAIL TIE TO VOTING SHOWN

Testimony Finds the Volume Rises Before Elections

WASHINGTON, June 1 (AP) — New court testimony and documents show that much of the mail Congress sends at taxpayer expense is tied directly to the re-election campaigns of Senate and House members. According to material filed in a lawsuit in Federal Court:

Senate Republicans put two direct-mail experts on the public payroll to advise them on how to use their free mailing privileges to get votes.

An election manual prepared for Senate Democrats refers to newsletters as a "free forum," and sets up a timetable

for sending them as an integral part of a model re-election campaign.

Senator John G. Tower, Republican of Texas, mailed more than 800,000 special-interest letters at taxpayer expense as part of his 1972 re-election effort and received campaign volunteer offers and donations in response.

Senator Jacob K. Javits, Republican of New York, gave written approval in 1973 for a tax-paid mail program intended to better his image and pay off at the polls. He focused his mail on areas where he needed votes.

The volume of "official" Congressional mail rises in election years and peaks just before the general election.

None of this activity necessarily violates any law or regulation, since Congress has wide discretion in the use of tax-paid mail. Congress gave itself the right to send official mail at Government expense at the

founding of the republic, and only Congress polices against abuses of the free mailings. Complaints of political use of the free-mailing privilege, called the franking privilege, are heard every election year.

Recently, however, the volume and cost of franked mail has multiplied. A new Federal law will limit what out-of-office challengers can spend to unseat incumbents.

In 1972, Congress passed a law prohibiting mass franked mailings within 28 days before an election. The sponsor of that legislation, Representative Morris K. Udall, Democrat of Arizona, said in an interview that further changes were needed to curtail political abuse of the frank.

Mr. Udall urged a 60-day pre-election cutoff for mass mailings and said he favored closing a loophole that recently allowed defeated Representative Frank M. Clark, Democrat of Pennsylvania, to send a

franked newsletter to his old constituents after he had left office. Mr. Clark is seeking to regain his old post.

Practice Documented

Seldom has the political use of franked mail been so well documented as in recent testimony and documents filed in a Federal Court by Common Cause, the lobby group, which is suing for an end to tax-financed mass mailings by Congress.

For example, Joyce P. Baker, a political mail specialist, said in a 1973 job proposal that she wanted to set up direct-mail programs for Republican Senators using franked mail. "The purpose of such a program is to help an incumbent Senator get re-elected," she said.

She was put on the Senate payroll at \$18,810 a year in 1973 and 1974 and testified that during that time she aided Republican Senators Robert J.

Dole of Kansas, Peter H. Domnick of Colorado, Charles McC. Mathias Jr. of Maryland.

Another political mail specialist, Lee W. MacGregor, wrote a proposal for the use of franked mail by his chief, Senator Javits, in 1973.

"The over-all objective of the franked mail program can be to get the recipient of the mail to identify positively with a particular stand you have taken or a bill you have introduced;

the kind of identification that can be translated into a vote at the polls on election day" Mr. MacGregor said.

Mr. Javits was out of the country and could not be reached. His administrative assistant, Donald Kellerman, defended the use of franked mail.

"It is a standard device to let voters, not voters but citizens, know what the Senator is doing here in Washington," he said.

Senator Tower's use of franked mail in his 1972 campaign was documented by memorandums.

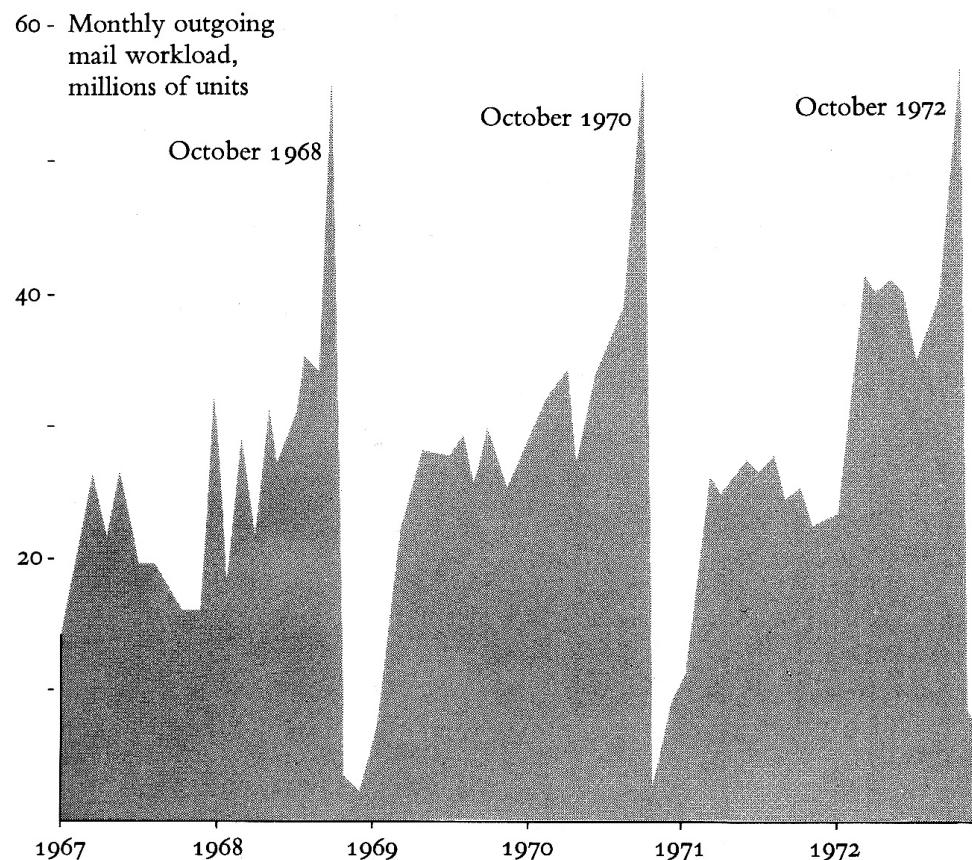
Tom Loeffler, a high-ranking campaign aide, wrote in a memorandum dated Oct. 27, 1972, that during the campaign Senator Tower had sent "31 special interest letters totaling approximately 803,333 franked mailings."

Mr. Tower was not available for comment. His administrative assistant, Elwin Skiles, said the Senator's use of franked mail in 1972 was within the law, and he defended the free-mailing privileges.

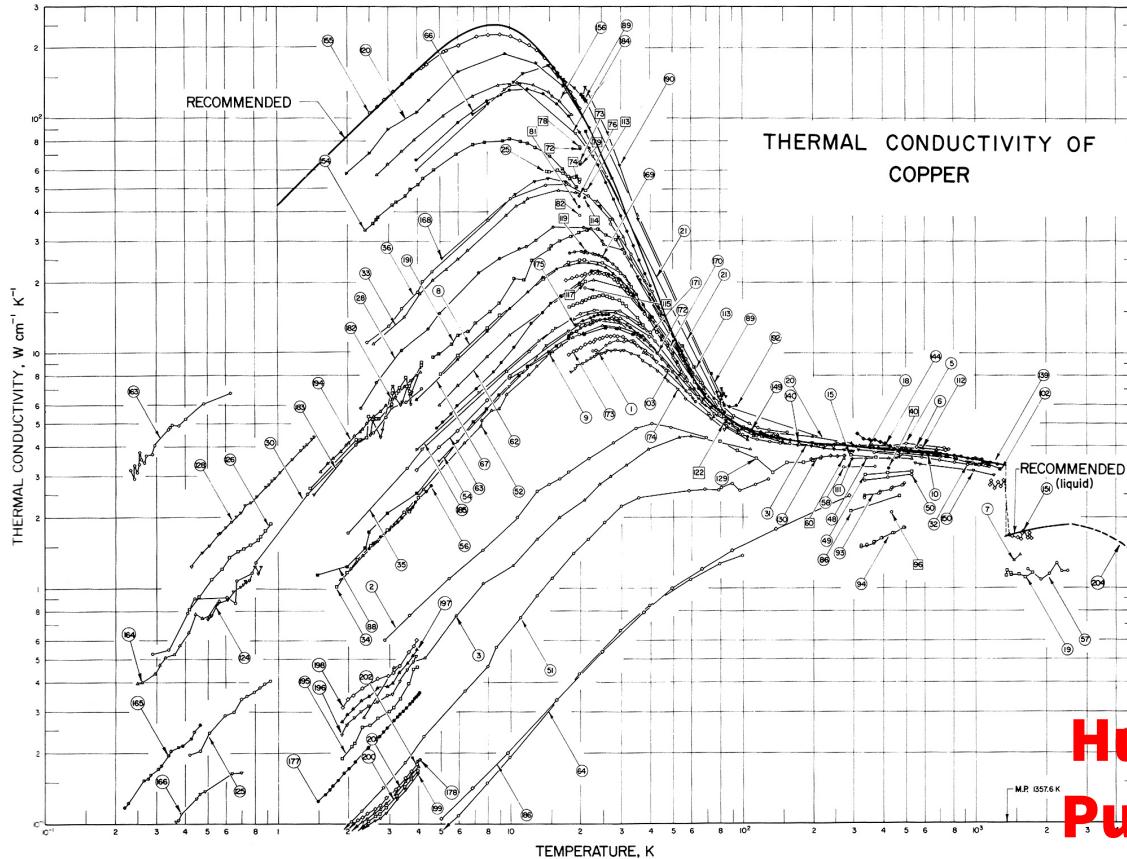
Postal Service figures show that in the 12 months before November, 1973, Congress sent 222.9 million franked pieces of mail. But in the next 12 months, covering the election season of 1974, Congress sent 350.6 million, a jump of 57 per cent about what's happening," Mr. Skiles said.

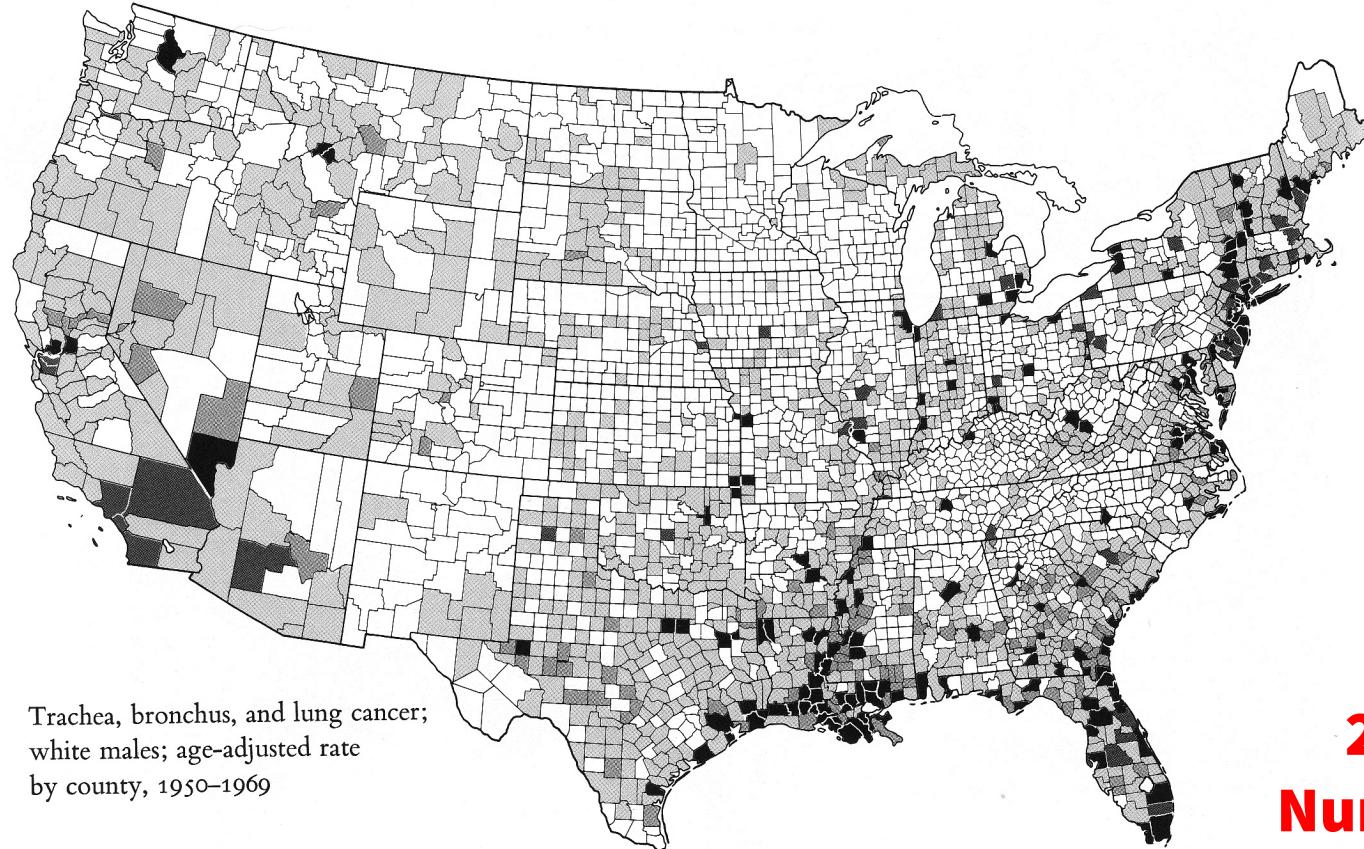
700 Words

VDQI Example (p37)



VDQI Example (p37)





VDQI Example (p18)

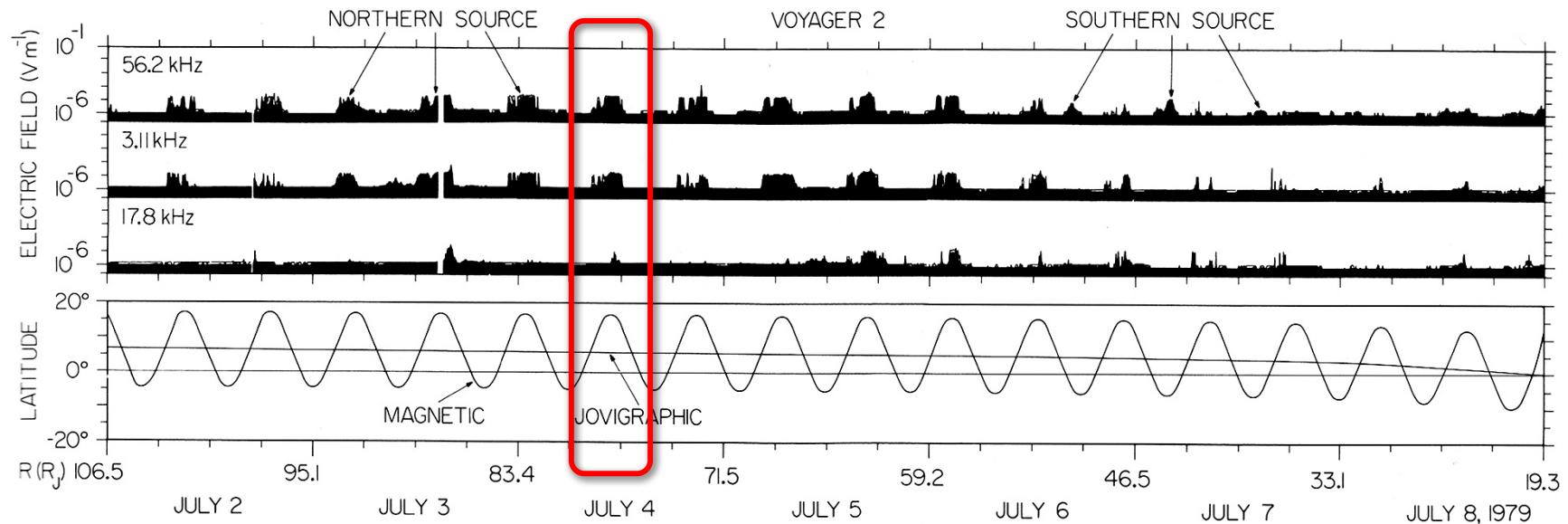
**21,000
Numbers**

Graphical Excellence

- Avoid distorting the data
- Reveal data at different levels of detail
- Present many numbers in a small space
- Encourage comparison ←
- Encourage viewers to think about the data, not graphic design, etc.



VDI Example (p24)



VDQI Example (p29)

Graphical Excellence

- A matter of **substance, statistics, and design**
- Consists of ideas communicated with **clarity, precision, and efficiency**
- Greatest number of ideas in **shortest** time and **smallest** space
- Nearly always **multivariate**

Graphical Excellence

“...requires telling the **truth** about the **data**.”

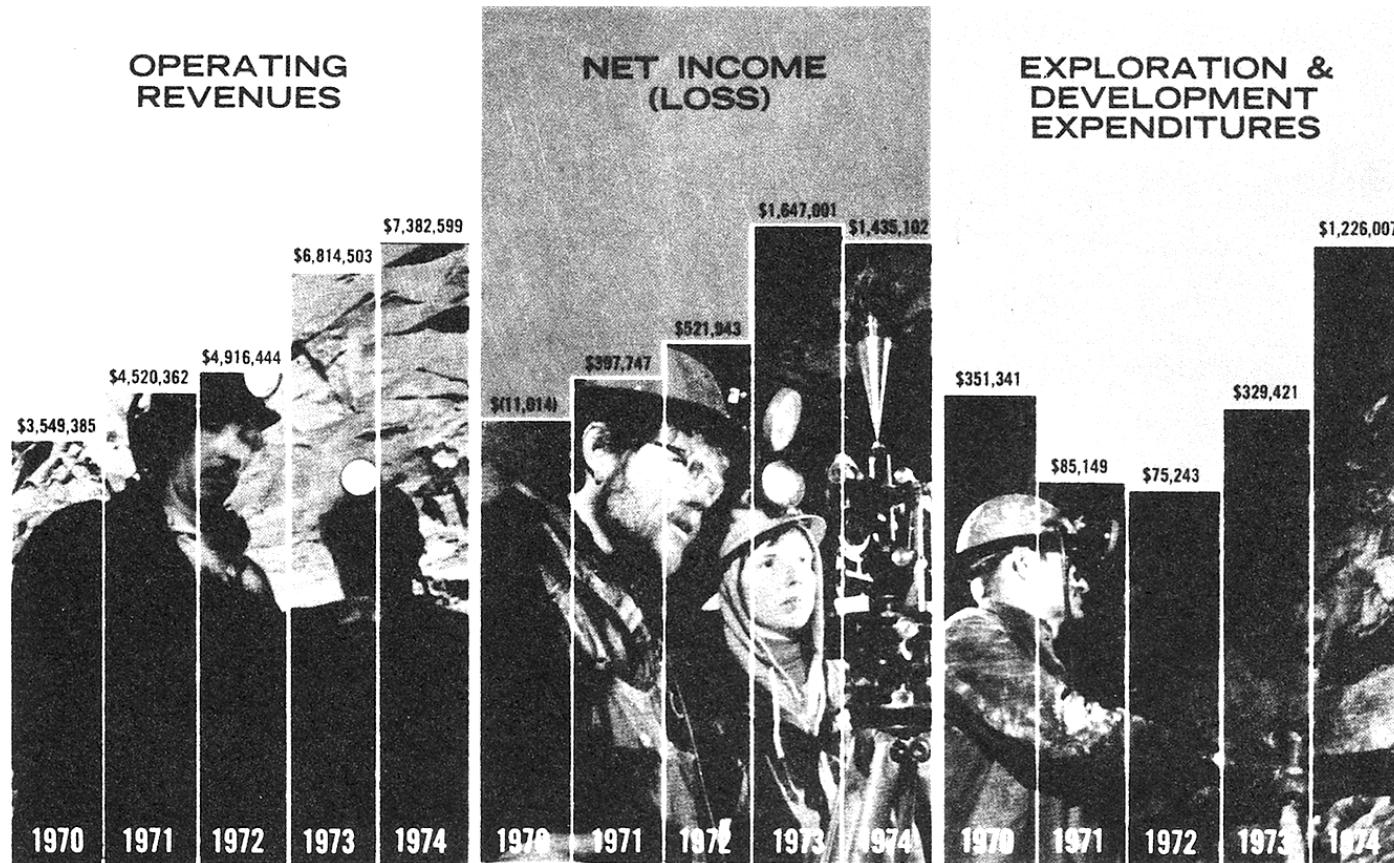
GRAPHICAL INTEGRITY

VDQI Chapter 2



Graphical Integrity

- Missing scales and labels ←
- Missing context
- Distorting scales
- Distorting design



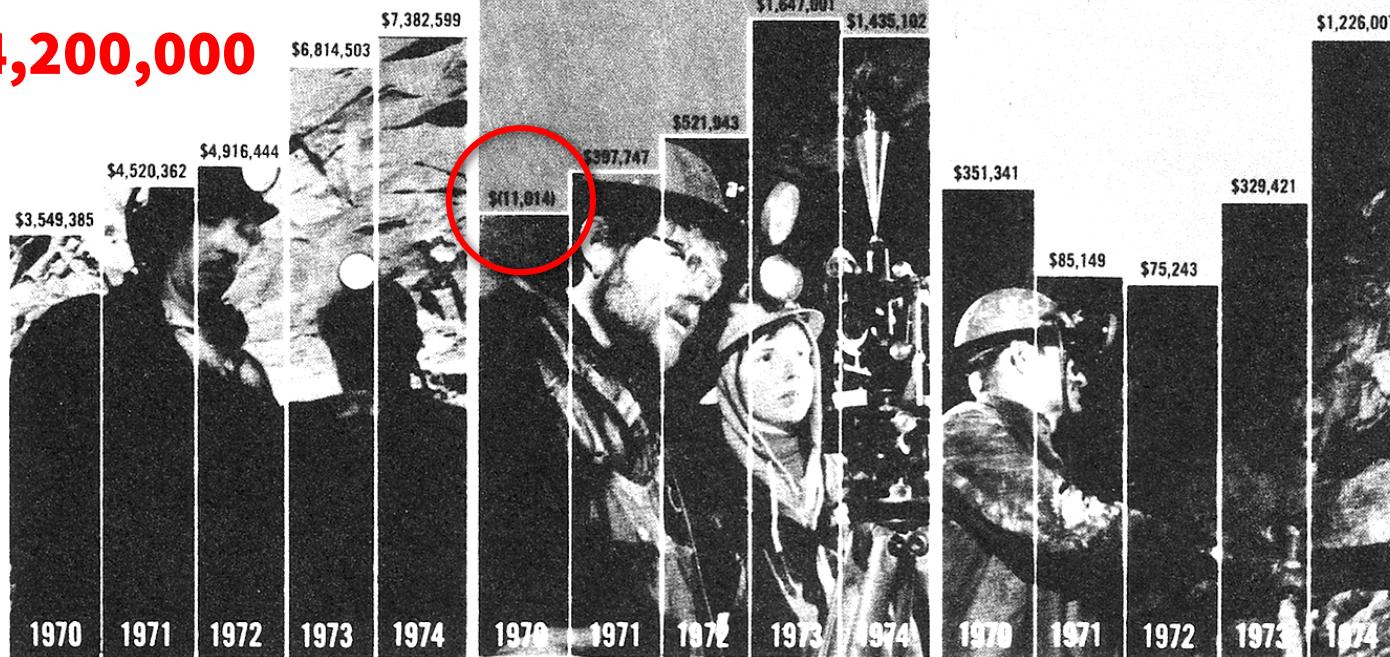
VDQI Example (p54)

OPERATING REVENUES

NET INCOME (LOSS)

EXPLORATION & DEVELOPMENT EXPENDITURES

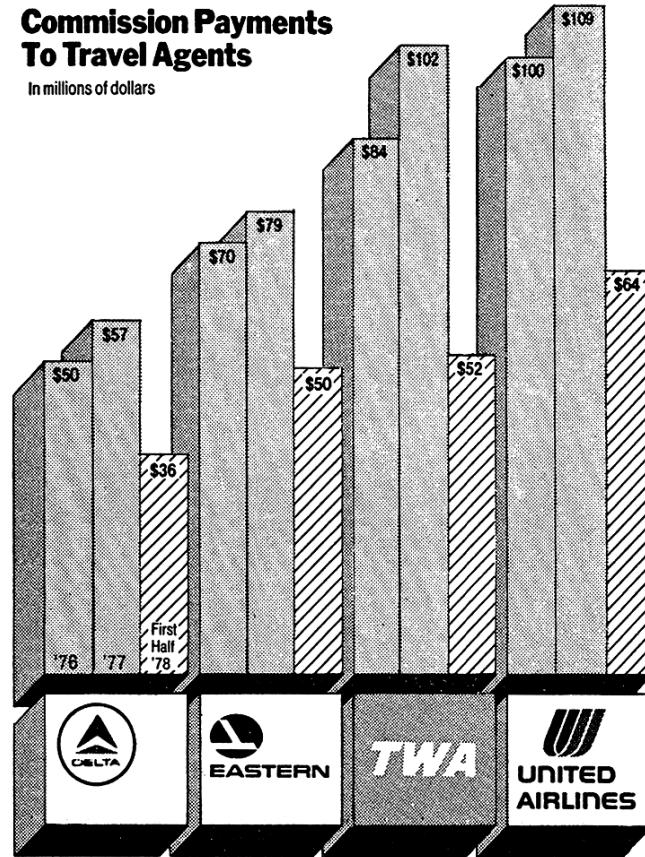
bottom of scale
 $\approx -\$4,200,000$



VDQI Example (p54)

Commission Payments To Travel Agents

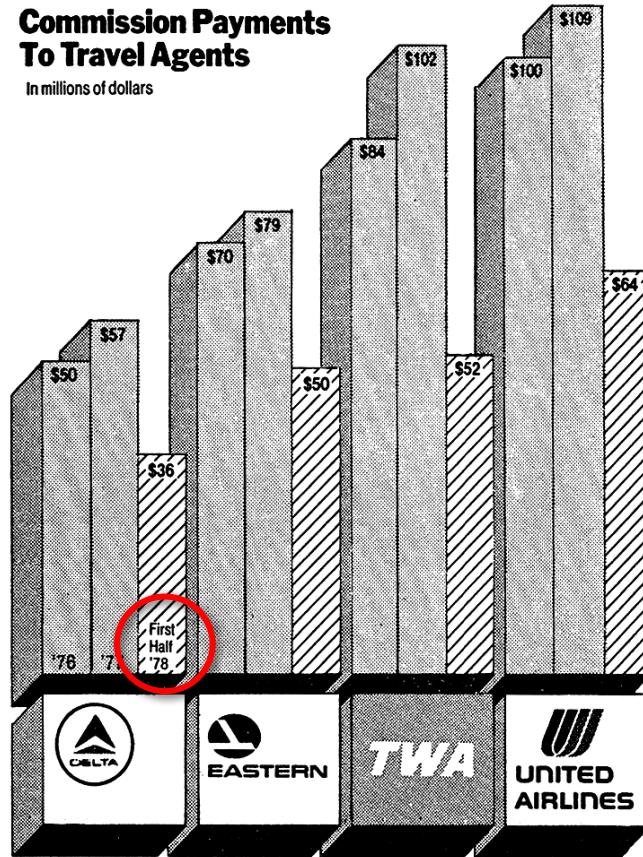
In millions of dollars



VDQI Example (p54)

Commission Payments To Travel Agents

In millions of dollars

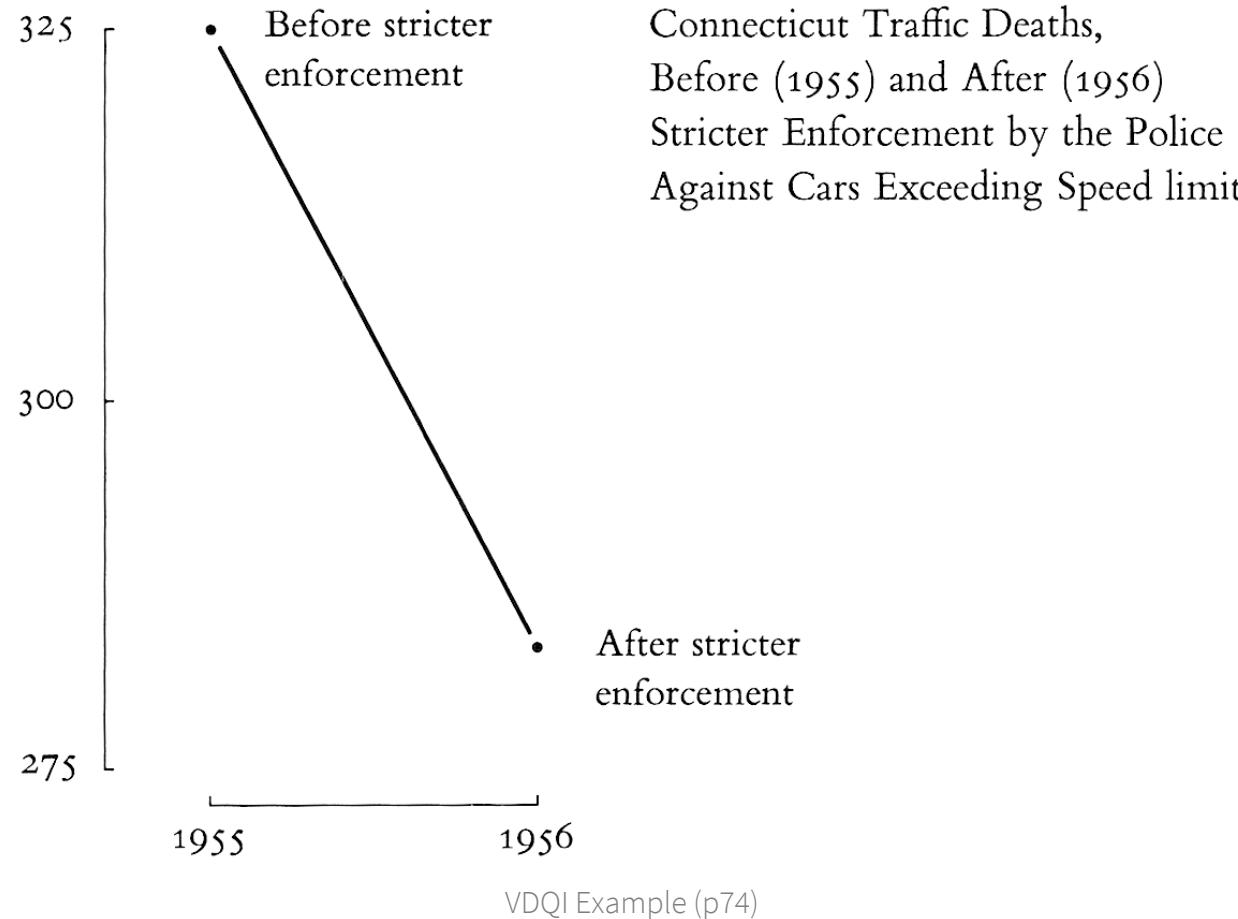


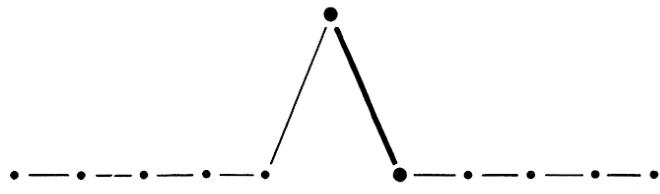
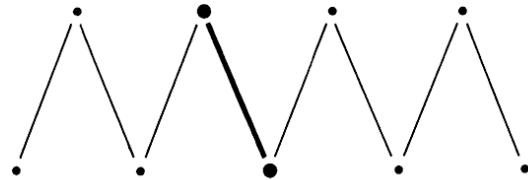
VDQI Example (p54)

- Pseudo-decline
- Comparing full years to a half year

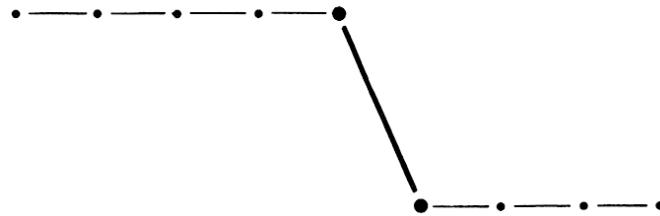
Graphical Integrity

- Missing scales and labels
- Missing context ←
- Distorting scales
- Distorting design

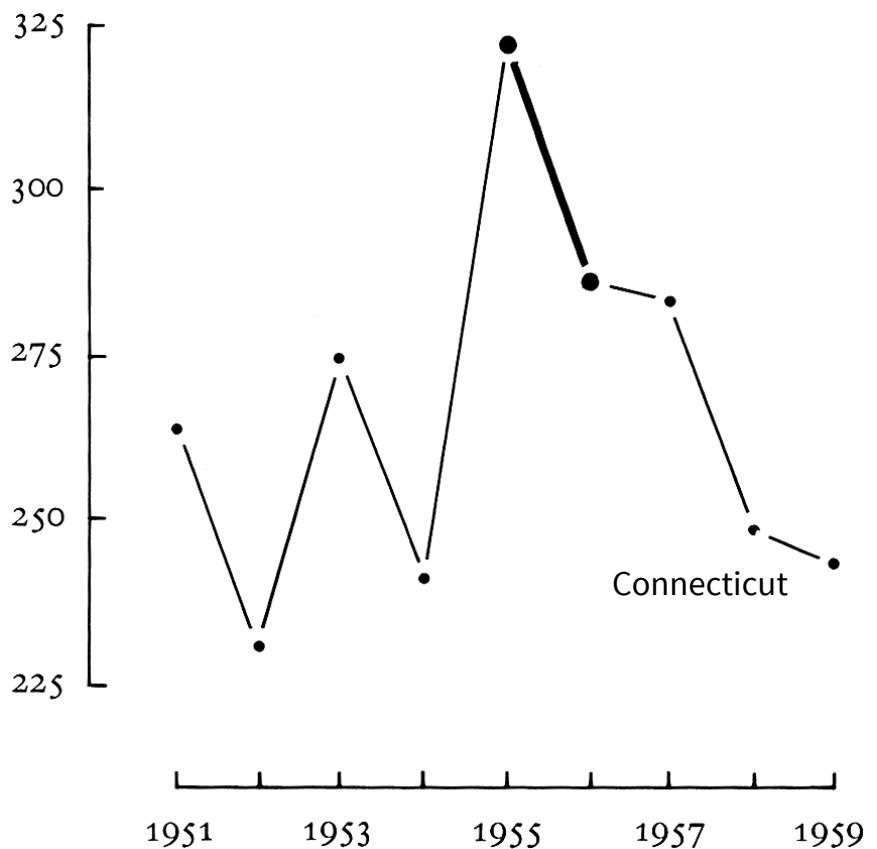




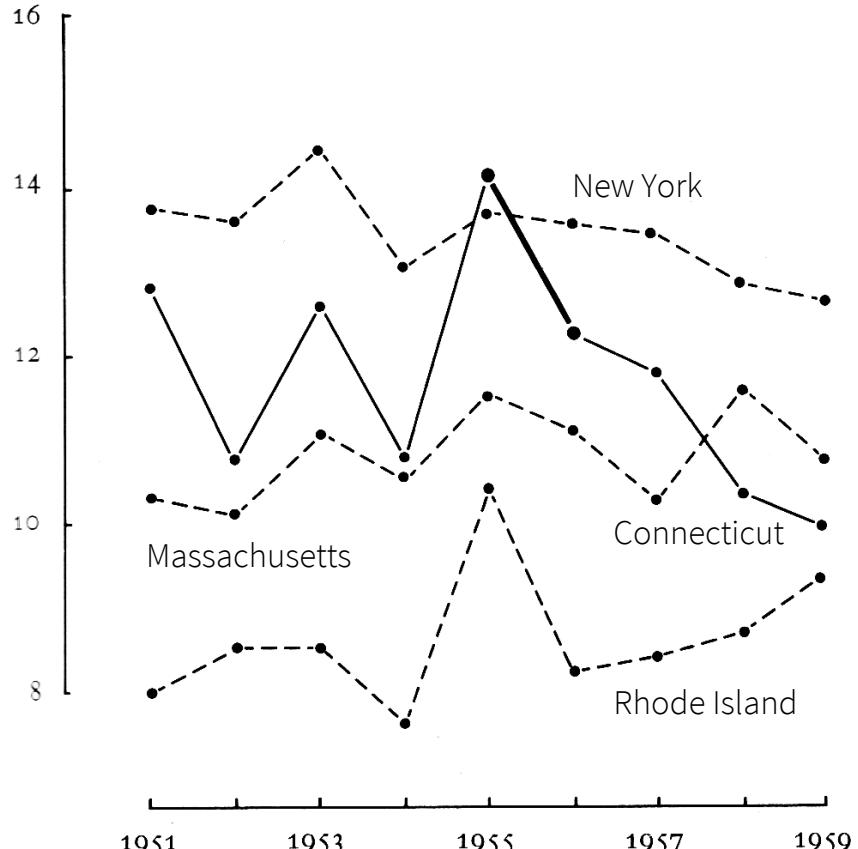
- Missing context
- Which pattern did this segment come from?



VDQI Example (p74)



VDQI Example (p74)

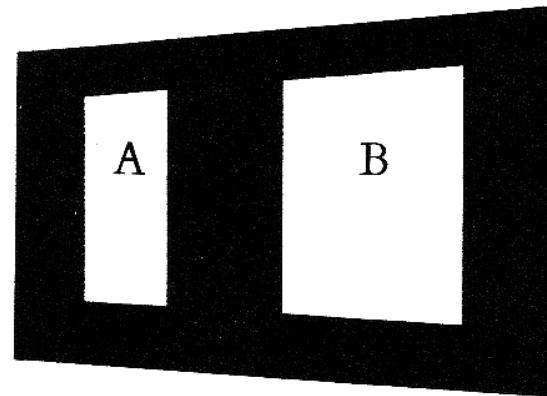
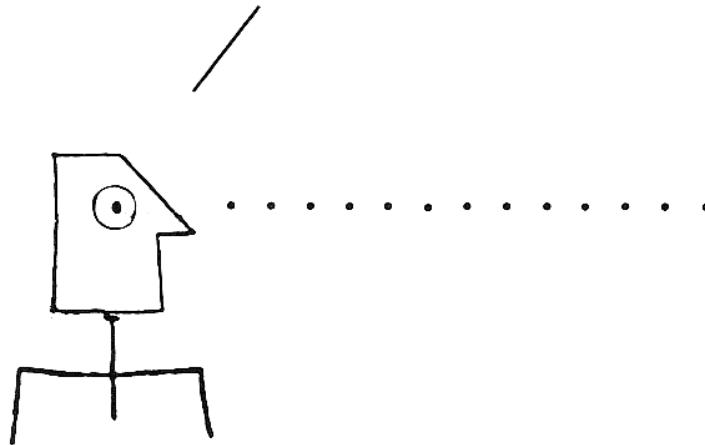


Graphical Integrity

- Missing scales and labels
- Missing context
- Distorting scales ←
- Distorting design

Distortion

I think I see that area B
is 3.14 times bigger than
area A. Is that correct?



Distortion: Problem

- Perceived area grows more slowly than actual area
- Perception changes per user
- Perception changes with experience
- Perception is context-dependent

Distortion: Solution*

- Physical representation should be directly  proportional to numerical quantities
- Use clear and detailed labeling
- Label important events in data

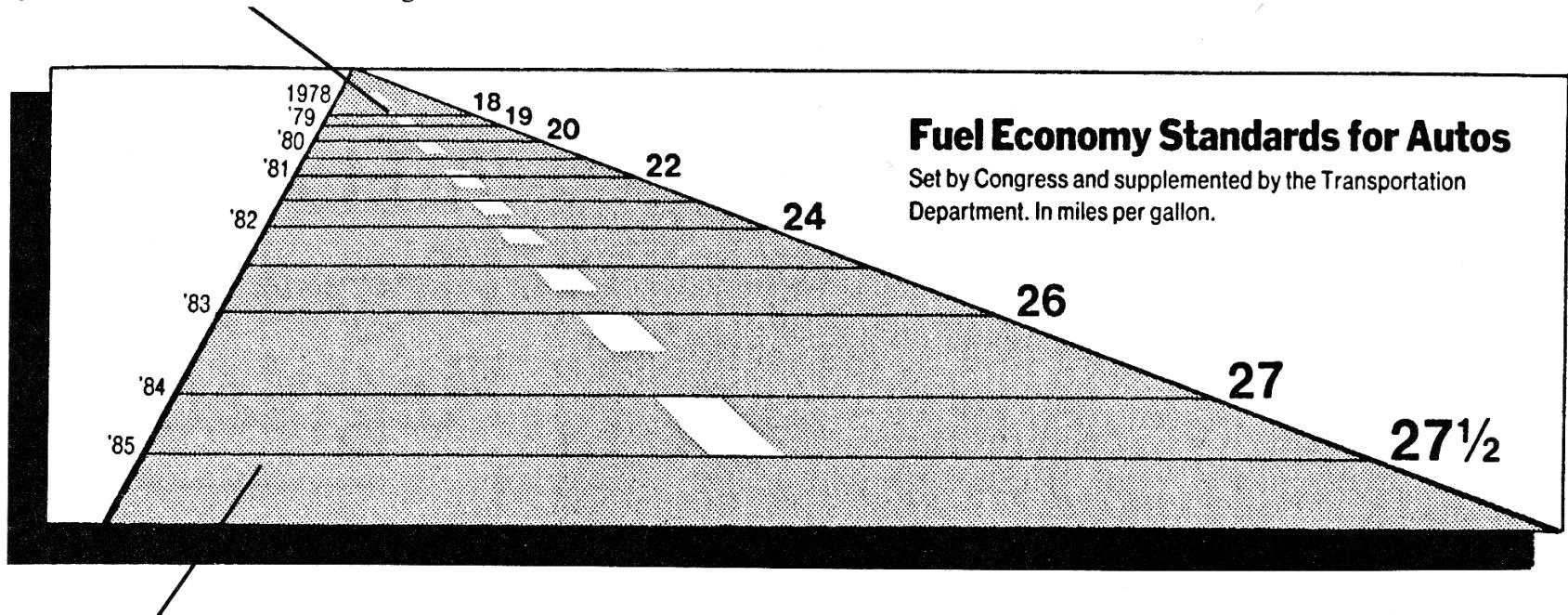
Lie Factor

$$\text{Lie Factor} = \frac{\text{size of effect shown in graphic}}{\text{size of effect in data}}$$

Lie factor should be close to one

i.e. $1.05 > \text{Lie Factor} > 0.95$

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



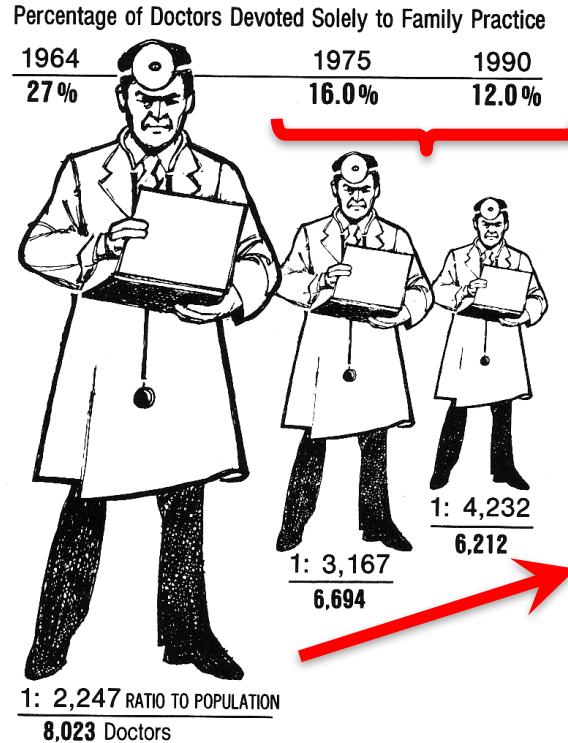
This line, representing 27.5 miles per gallon in 1985, is 5.3 inches long.

$$\frac{27.5 - 18.0}{18.0} = 0.53 \quad \frac{5.3 - 0.6}{0.6} = 7.83 \quad \text{Lie Factor} = \frac{7.83}{0.53} = 14.8$$

VDQI Example (p57)

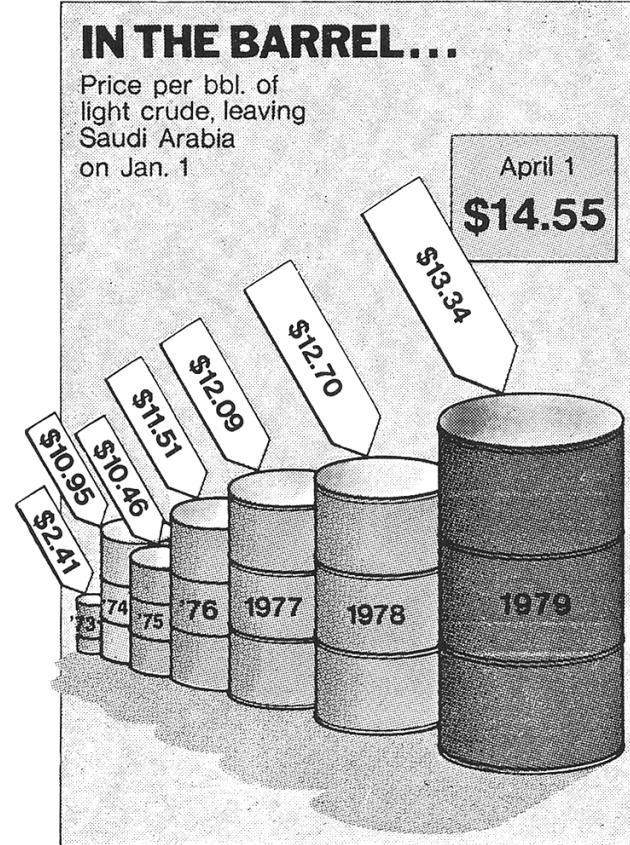
THE SHRINKING FAMILY DOCTOR

In California



- Lie factor of 2.8
- Additionally:
 - Exaggeration from perspective
 - Incorrect horizontal spacing

VDQI Example (p69)

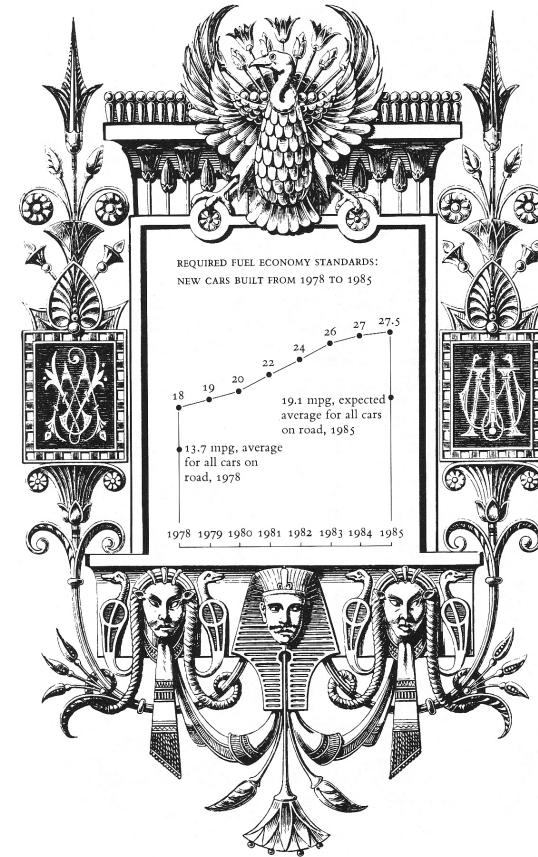
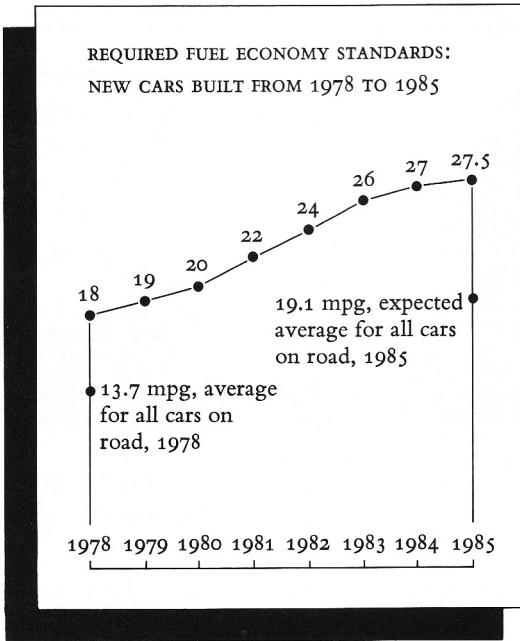


VDQI Example (p71)

- Surface area lie factor: 9.4
- Volume lie factor: 59.4
- Don't use 2D or 3D to show 1D data!

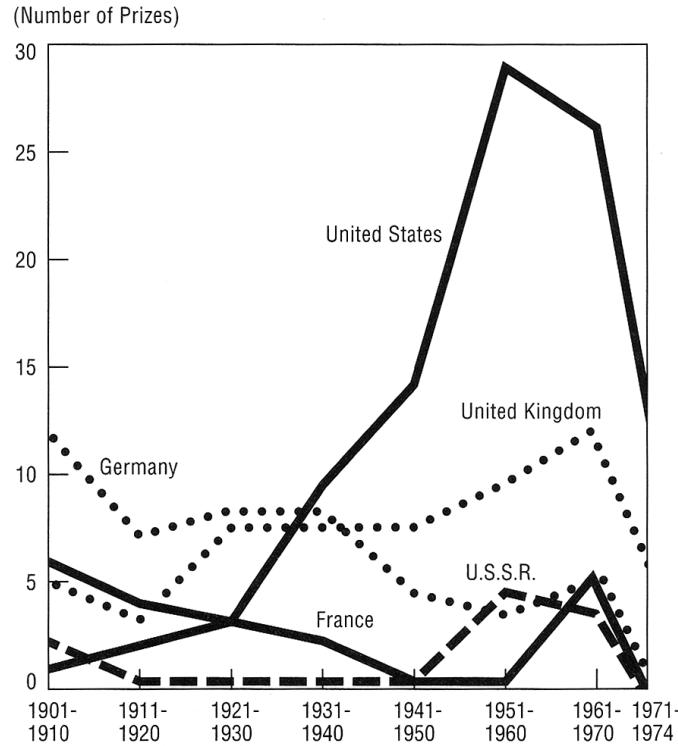
Graphical Integrity

- Missing scales and labels
- Missing context
- Distorting scales
- Distorting design ←



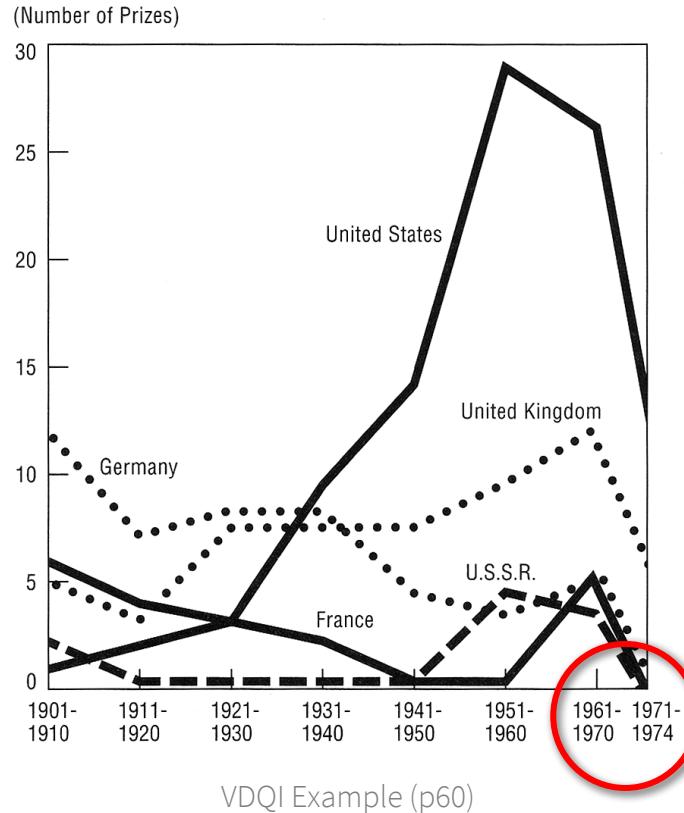
VDQI Example (p58)

Nobel Prizes Awarded in Science, for Selected Countries, 1901-1974

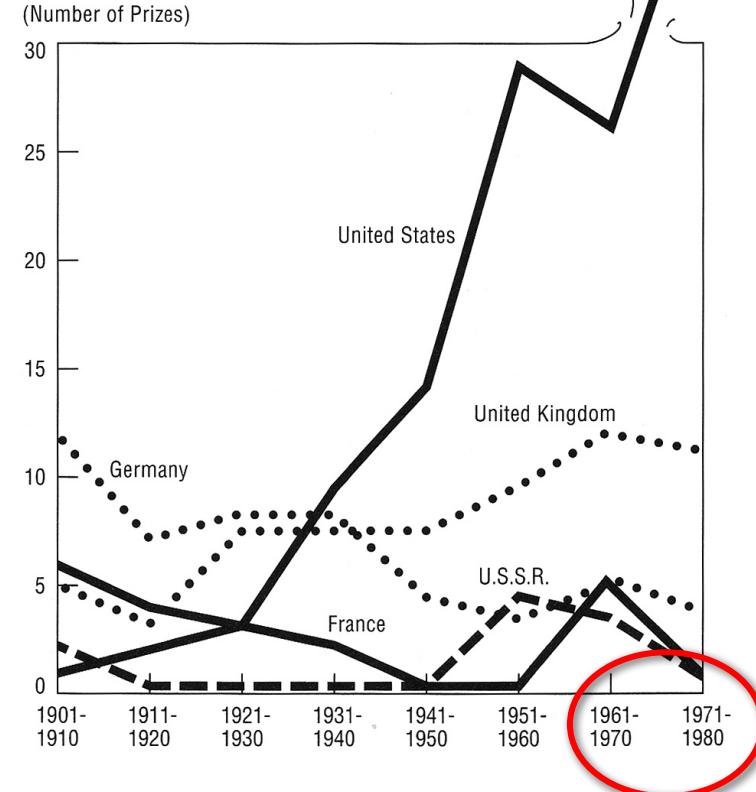


VDQI Example(p60)

Nobel Prizes Awarded in Science, for Selected Countries, 1901-1974

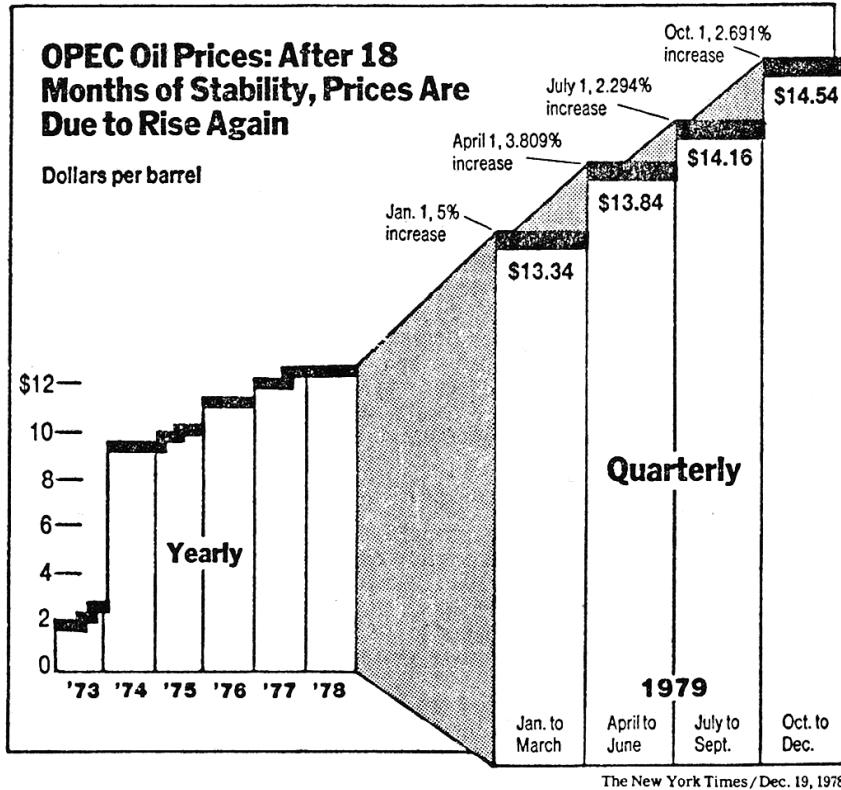


Nobel Prizes Awarded in Science, for Selected Countries, 1901-1980



Graphical Integrity

- Missing scales and labels
- Missing context
- Distorting scales
- Distorting design
 - Show ***data variation***, not ***design variation***



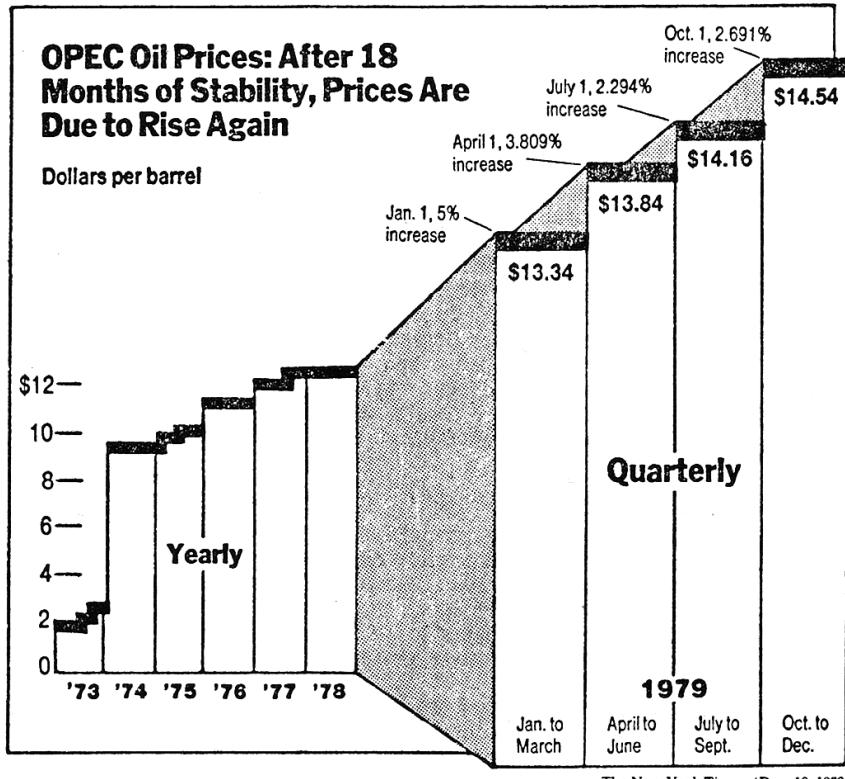
- **Vertical Scales**

- 1973 to 1978: \$8.00 per inch
- 1979: \$4.00 per inch

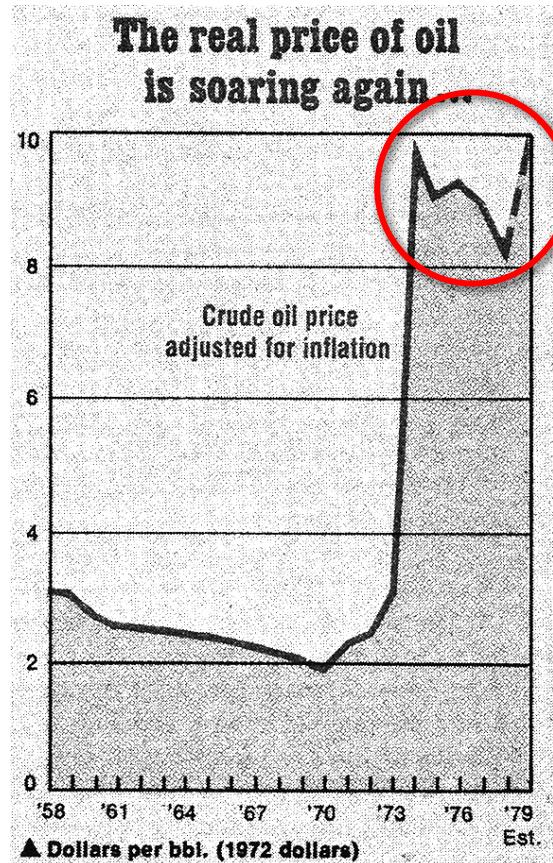
- **Horizontal Scales**

- 1973 to 1978: 3.8 years per inch
- 1979: 0.57 years per in

VDQI Example (p61)

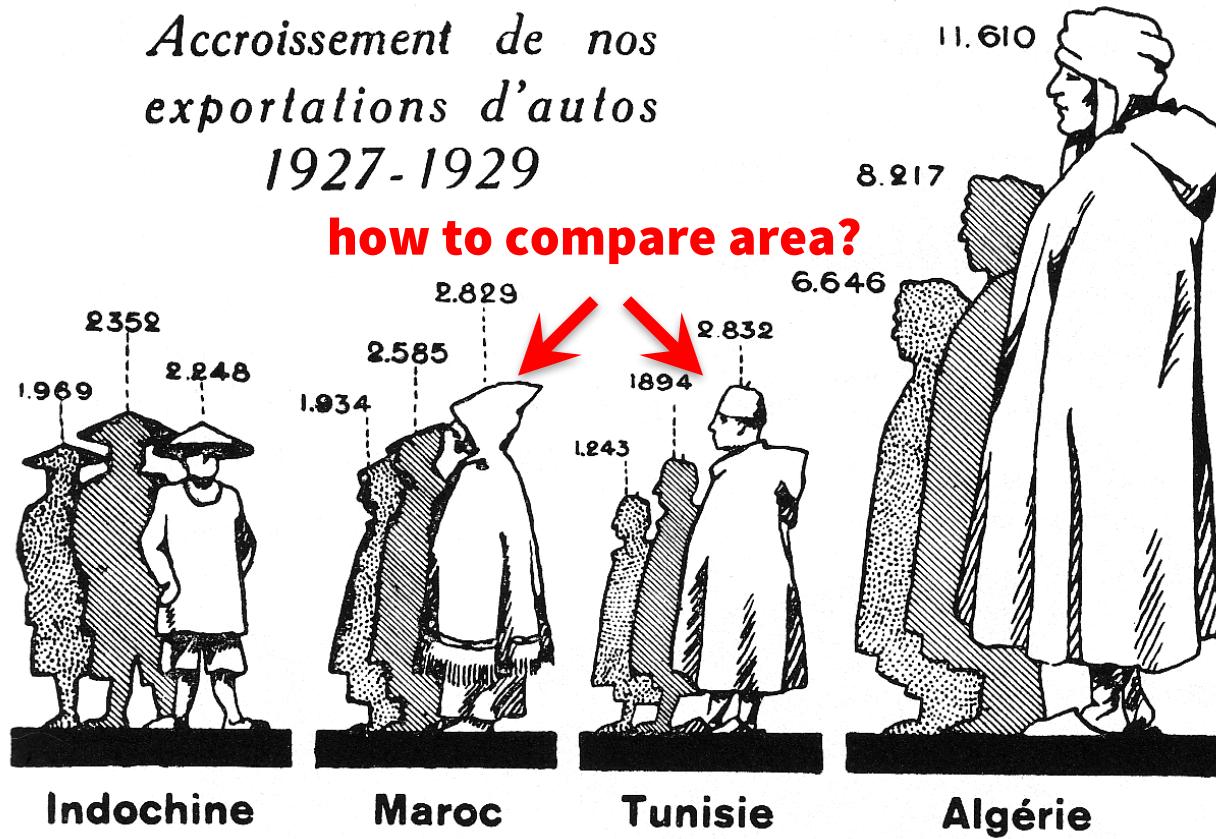


VDQI Example (p61)



*Accroissement de nos
exportations d'autos
1927-1929*

how to compare area?

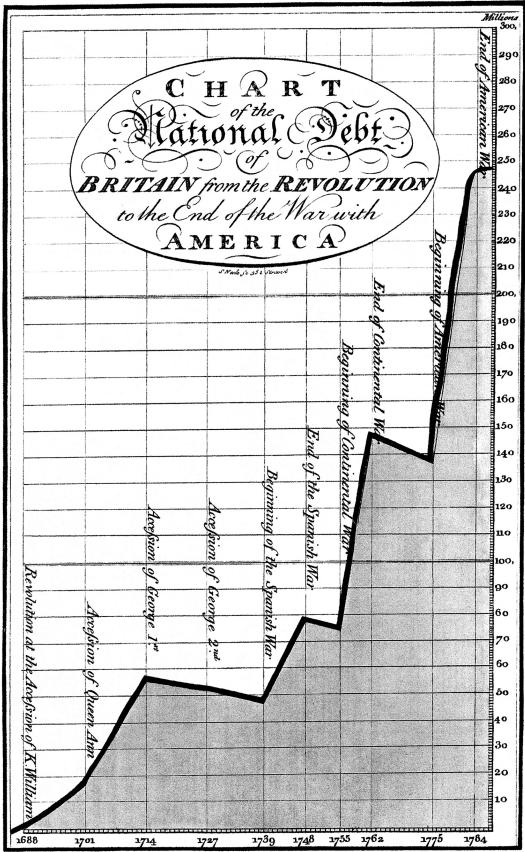


VDQI Example (p69)

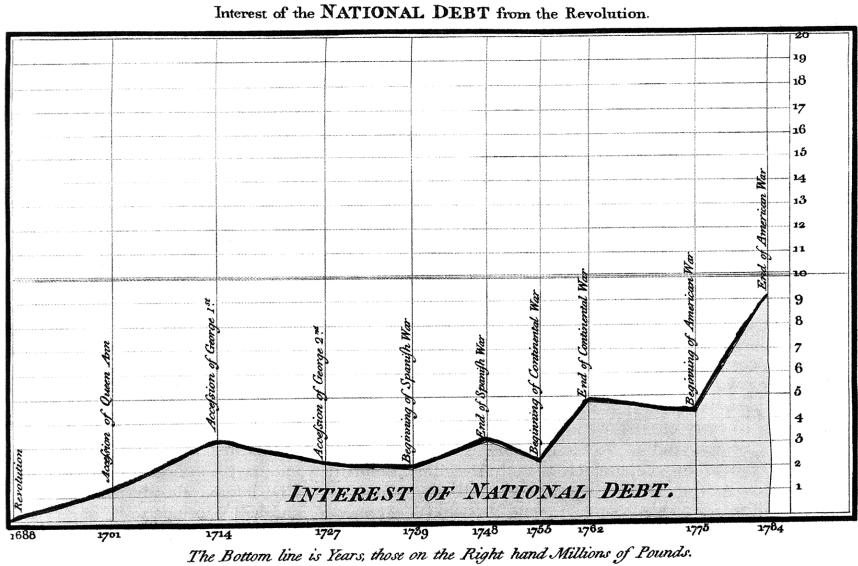


GRAPHICAL INTEGRITY

Government Spending Example

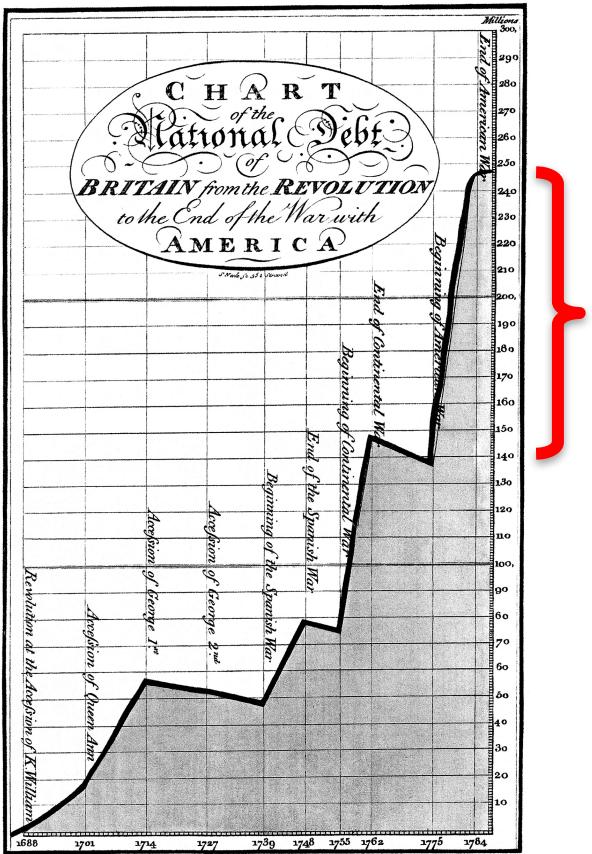


VDI Example (p64)

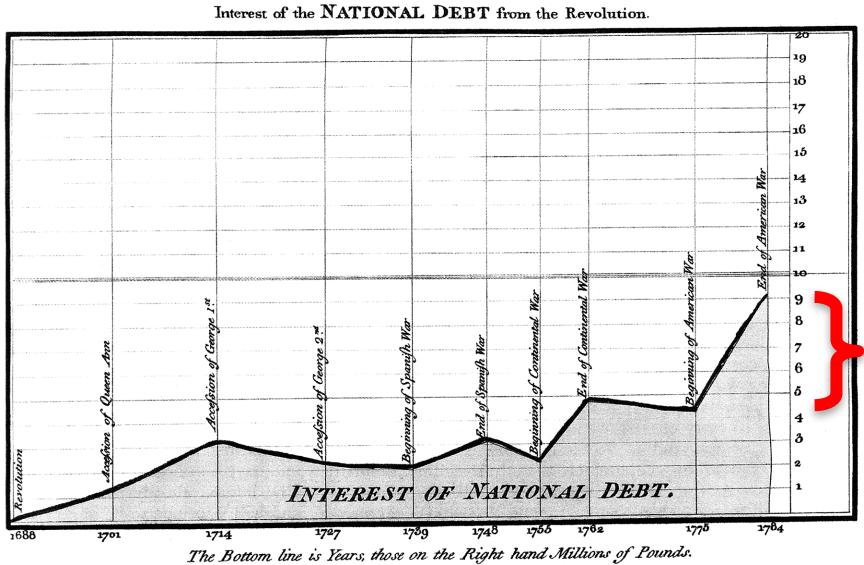


Graphical Integrity

- Tall versus wide graphic emphasizes growth 
- Wide versus tall graphic emphasizes time
- Gimmicks emphasizes different aspects
- Counts versus ratios don't provide context

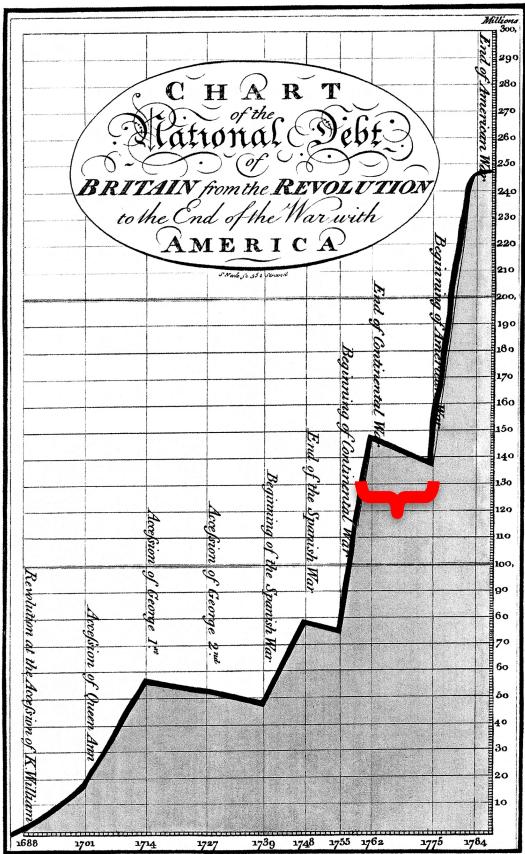


VDI Example (p64)

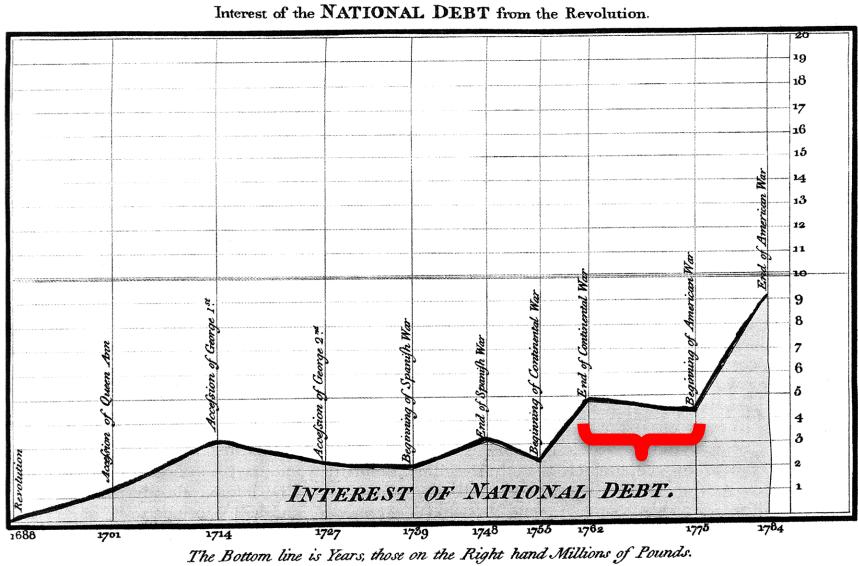


Graphical Integrity

- Tall versus wide graphic emphasizes growth
- Wide versus tall graphic emphasizes time ←
- Gimmicks emphasizes different aspects
- Counts versus ratios don't provide context



VDI Example (p64)



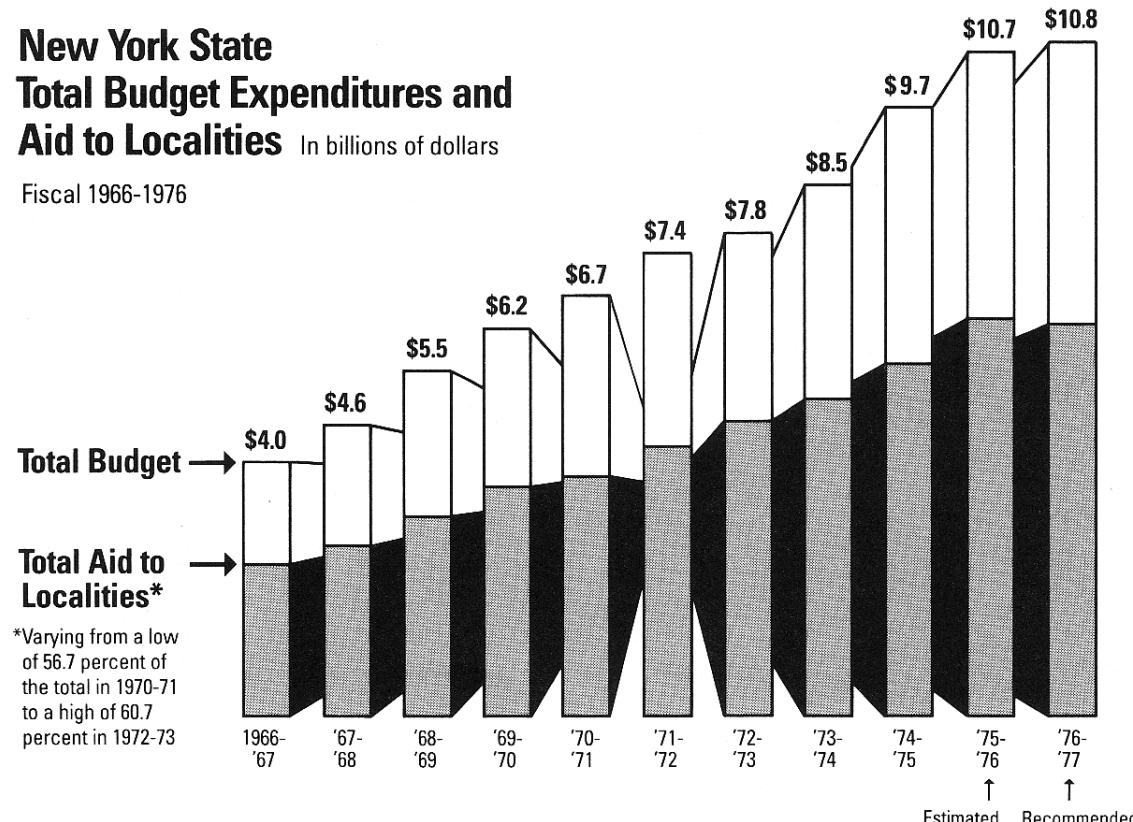
Graphical Integrity

- Tall versus wide graphic emphasizes growth
- Wide versus tall graphic emphasizes time
- Gimmicks emphasizes different aspects ←
- Counts versus ratios don't provide context

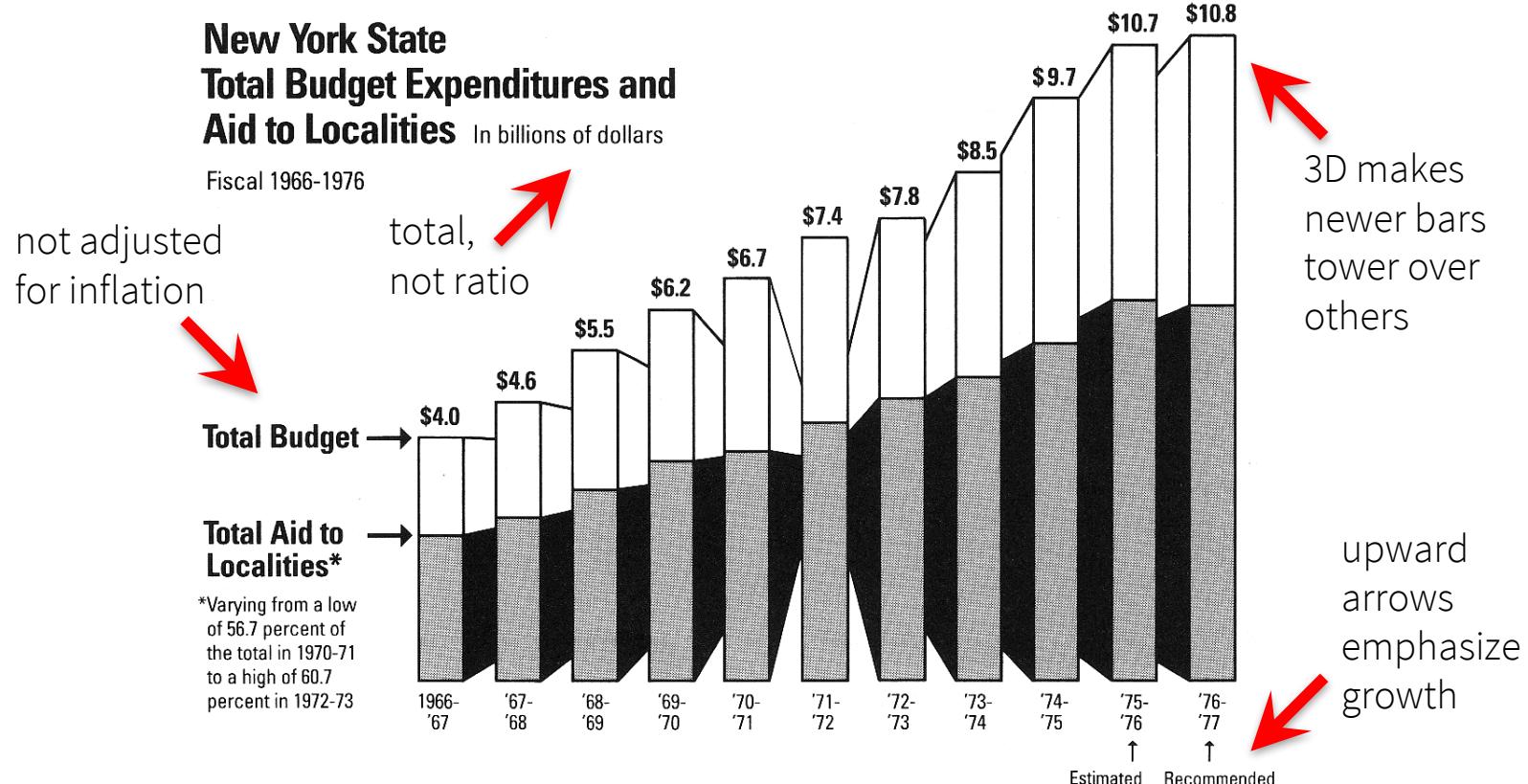
New York State Total Budget Expenditures and Aid to Localities

In billions of dollars

Fiscal 1966-1976

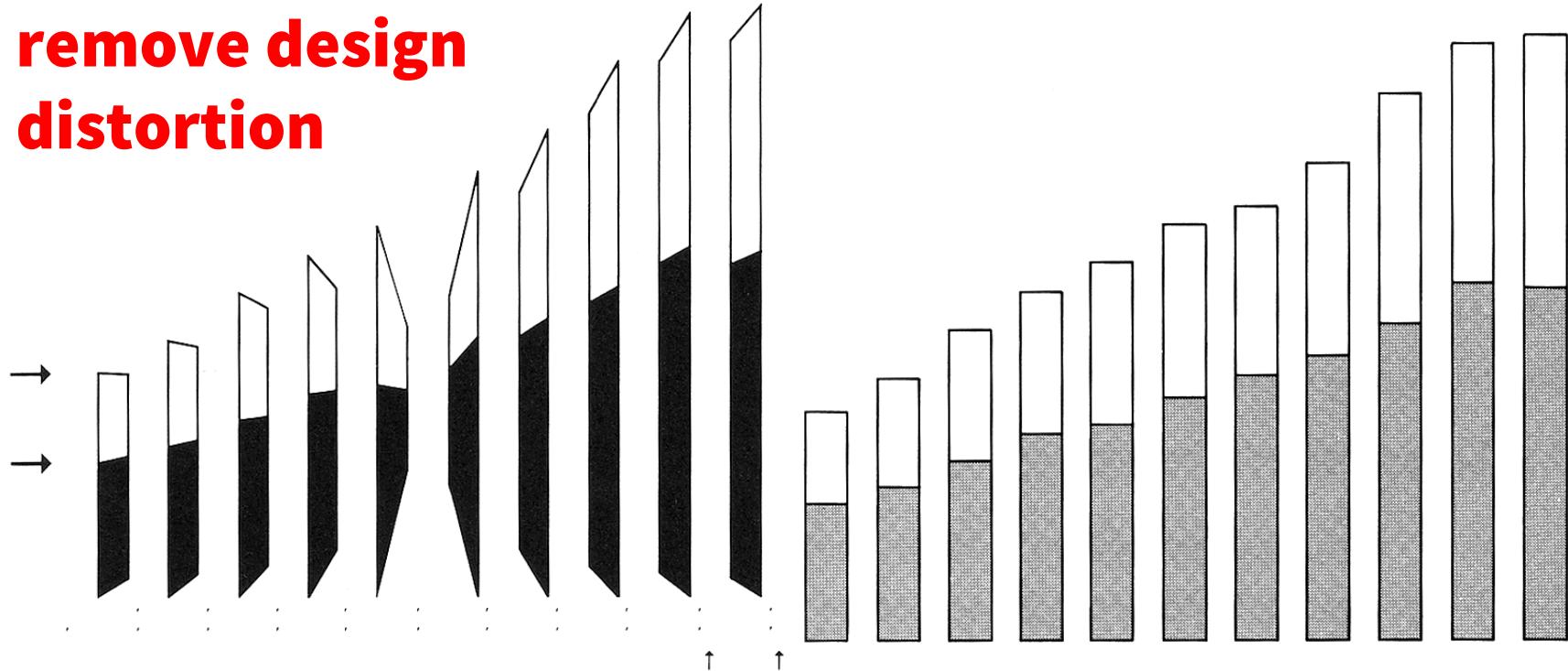


VDQI Example (p66)



VDQI Example (p66)

remove design distortion

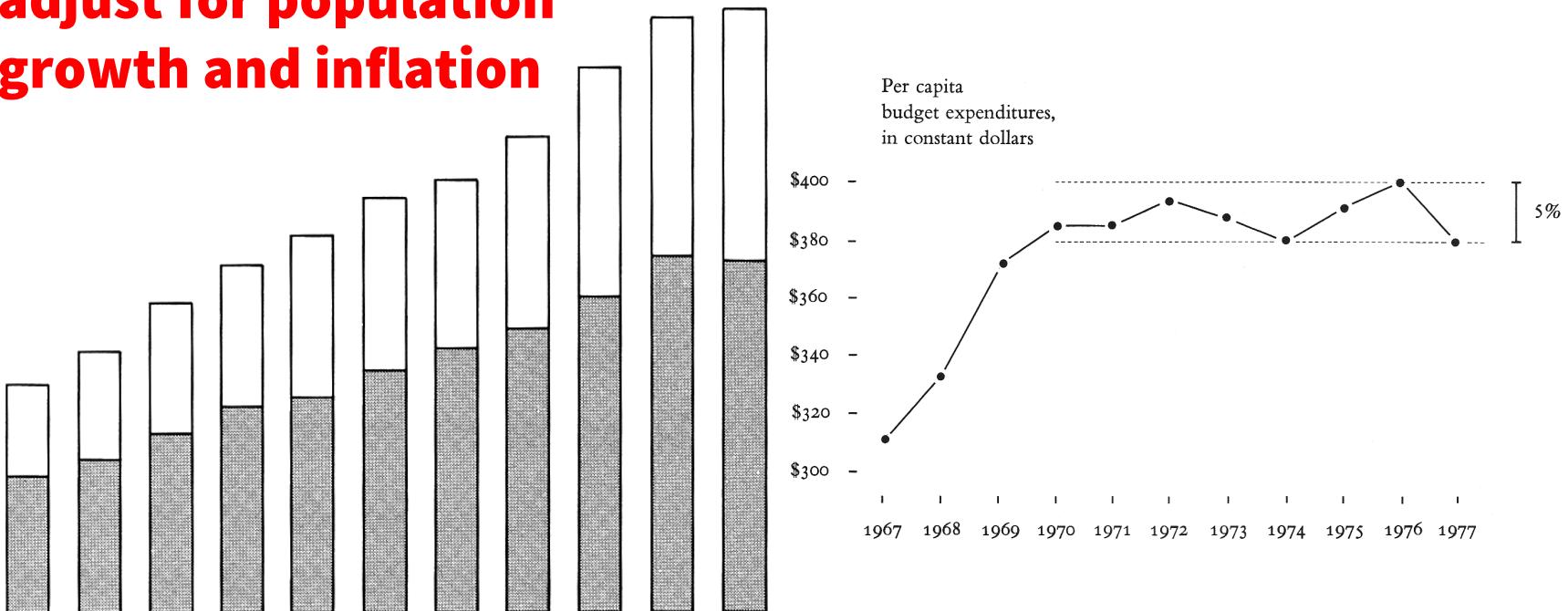


VDQI Example (p66)

Graphical Integrity

- Tall versus wide graphic emphasizes growth
- Wide versus tall graphic emphasizes time
- Gimmicks emphasizes different aspects
- Counts versus ratios don't provide context 

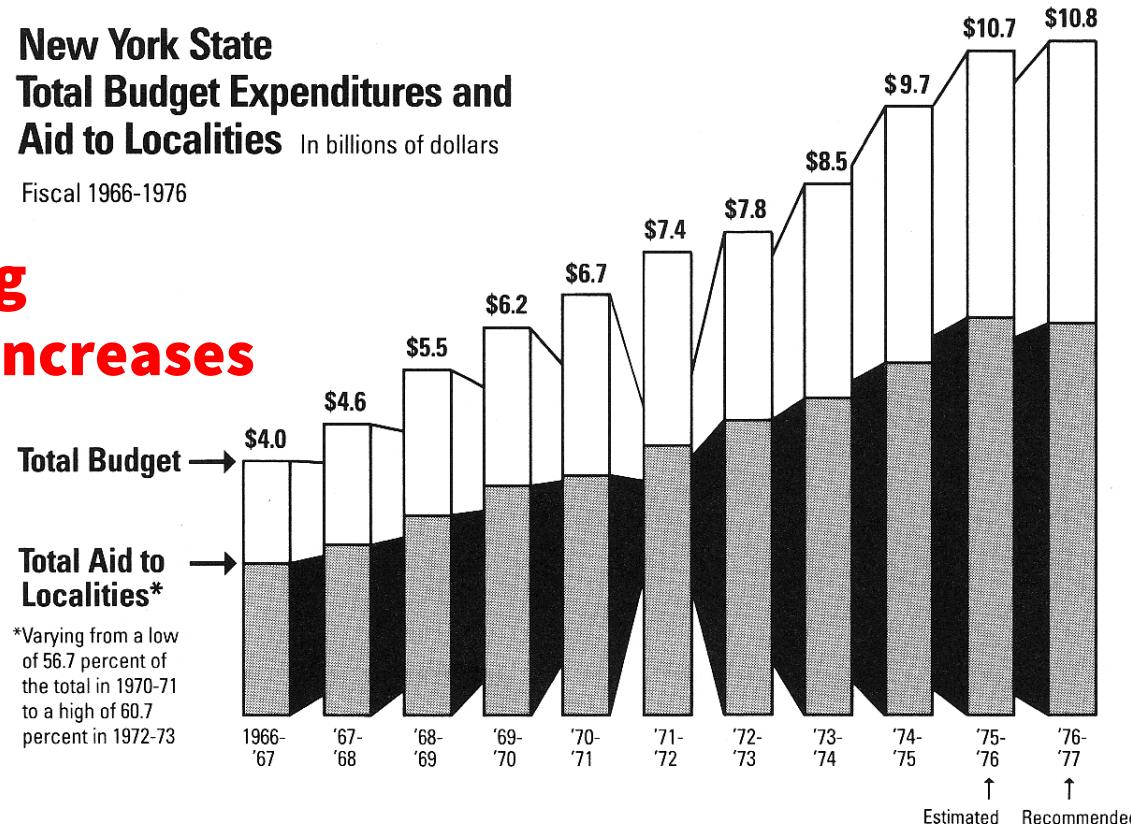
adjust for population growth and inflation



VDQI Example (p66)

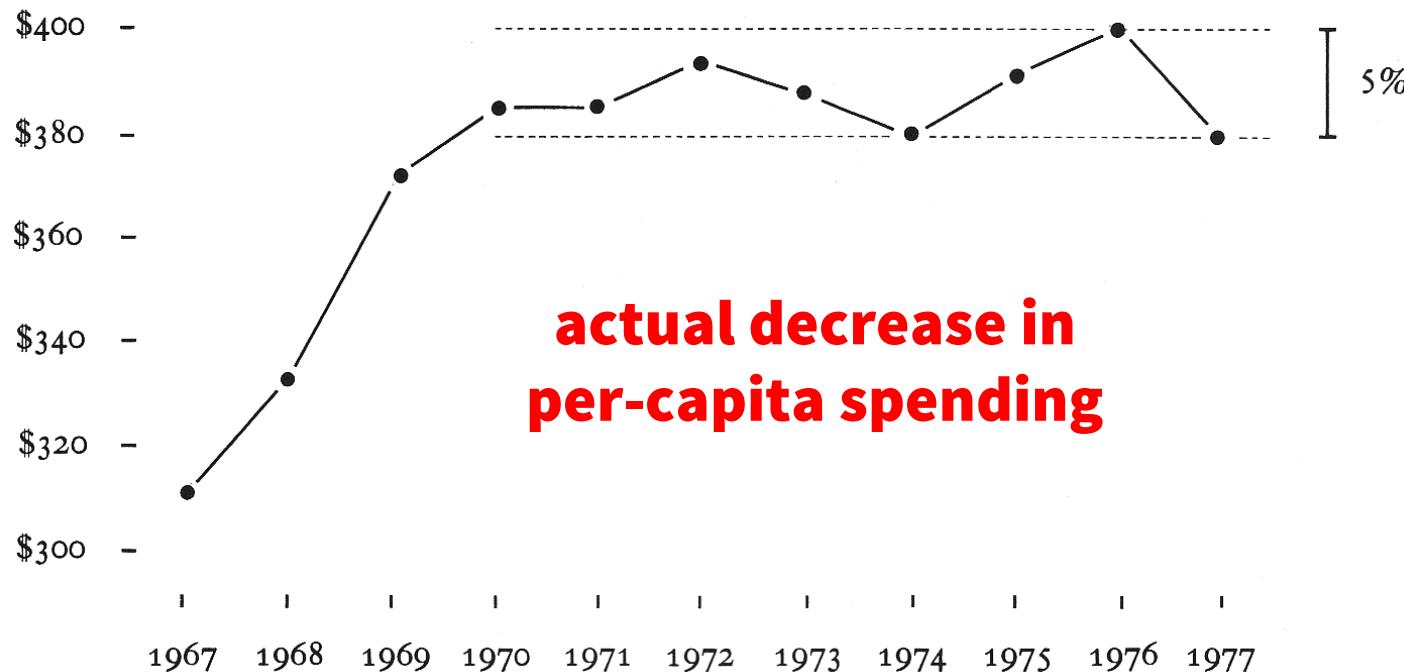
New York State
Total Budget Expenditures and
Aid to Localities In billions of dollars
 Fiscal 1966-1976

**towering
budget increases**



VDQI Example (p66)

Per capita
budget expenditures,
in constant dollars



VDQI Example (p66)

Lessons Learned

- Beware emphasis caused by tall versus wide graphs
- Beware gimmicks overemphasizing data
- Beware counts versus ratios
- Beware un-adjusted numbers (e.g. dollars versus dollars adjusted for inflation)

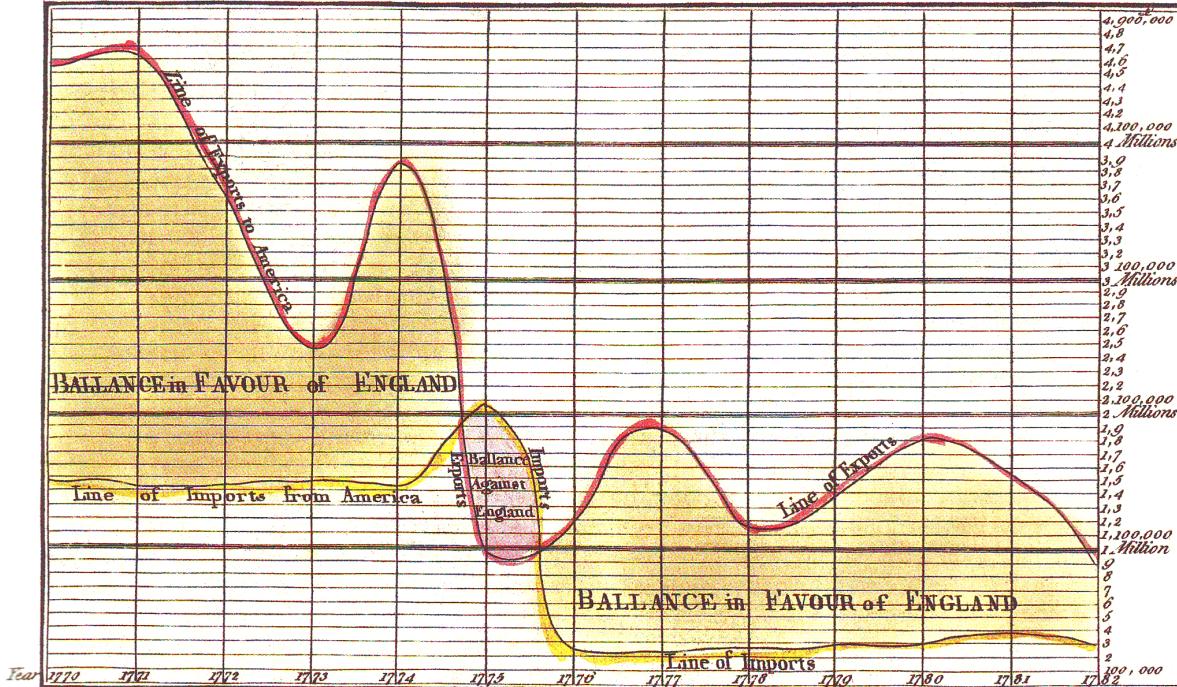
GRAPHICAL REDESIGN

VDQI Chapter 4



Above all else, show the data.

*CHART of IMPORTS and EXPORTS of ENGLAND to and from all NORTHAMERICA
From the Year 1770 to 1782 by W. Playfair*



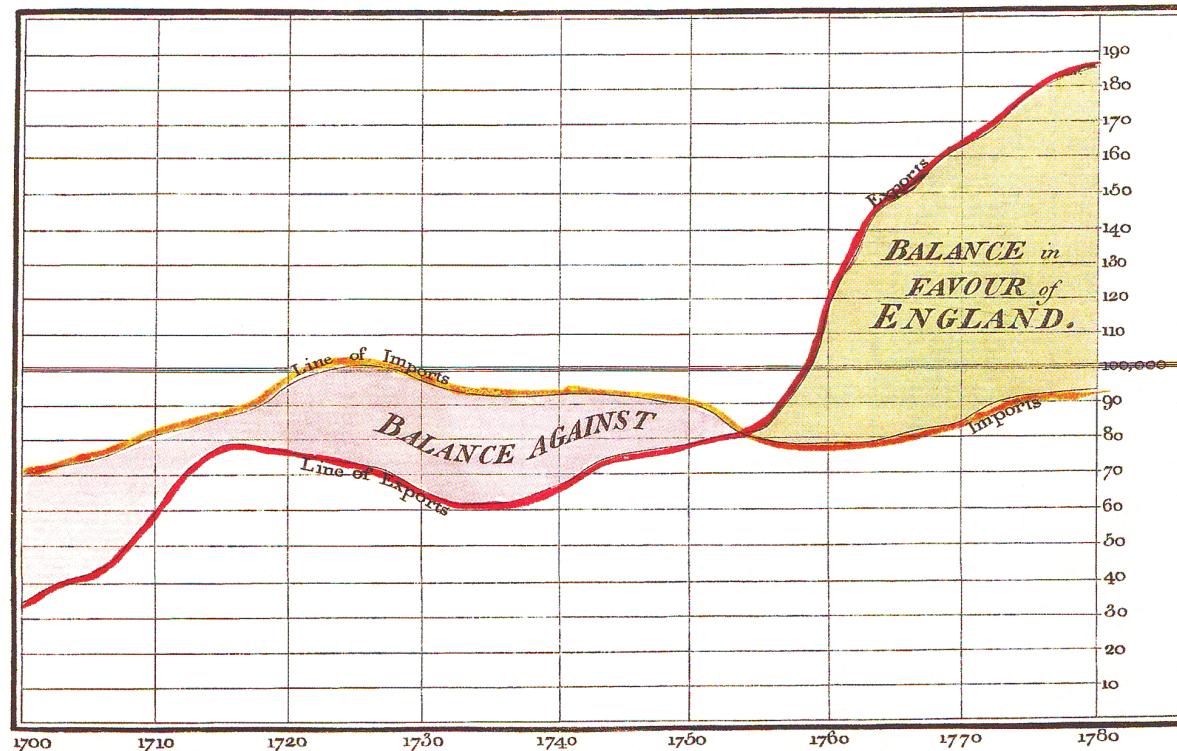
The Bottom Line is divided into Years the right-hand Line into HUNDRED THOUSAND POUNDS

J. Anstie Sculp.

Published as the Act directs 20th Aug^t 1805.

VDQI Example (p91)

Exports and Imports to and from DENMARK & NORWAY from 1700 to 1780.



The Bottom line is divided into Years, the Right hand line into £10,000 each.

Published as the Act directs, 1st May 1786, by Wm. Playfair

Neck sculpt. 352, Strand, London.

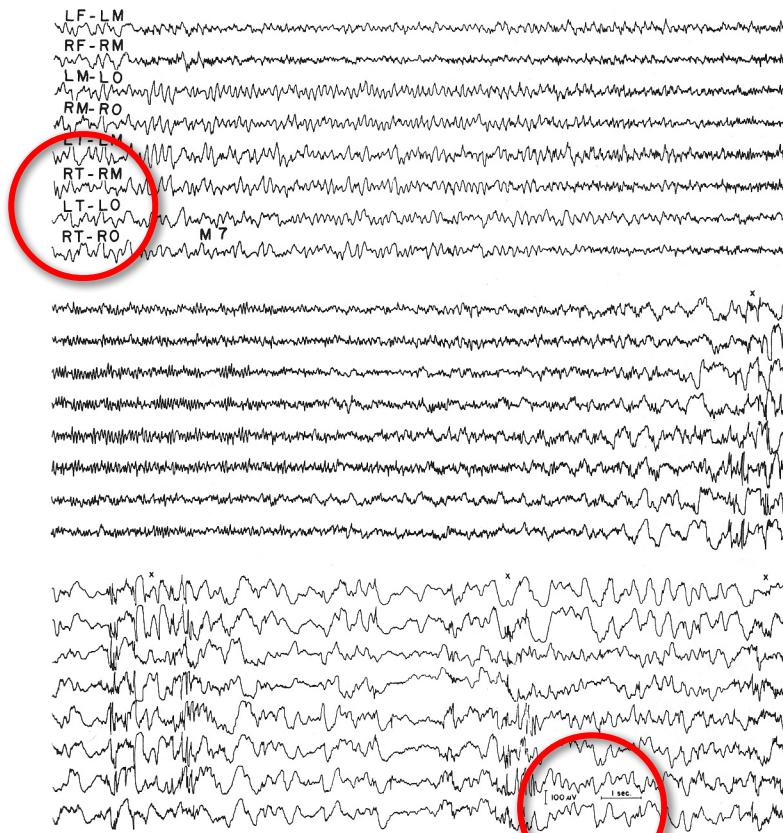
VDQI Example (p91)

Data-Ink Ratio

$$\text{Data-Ink Ratio} = \frac{\text{data-ink}}{\text{total ink used in graphic}}$$

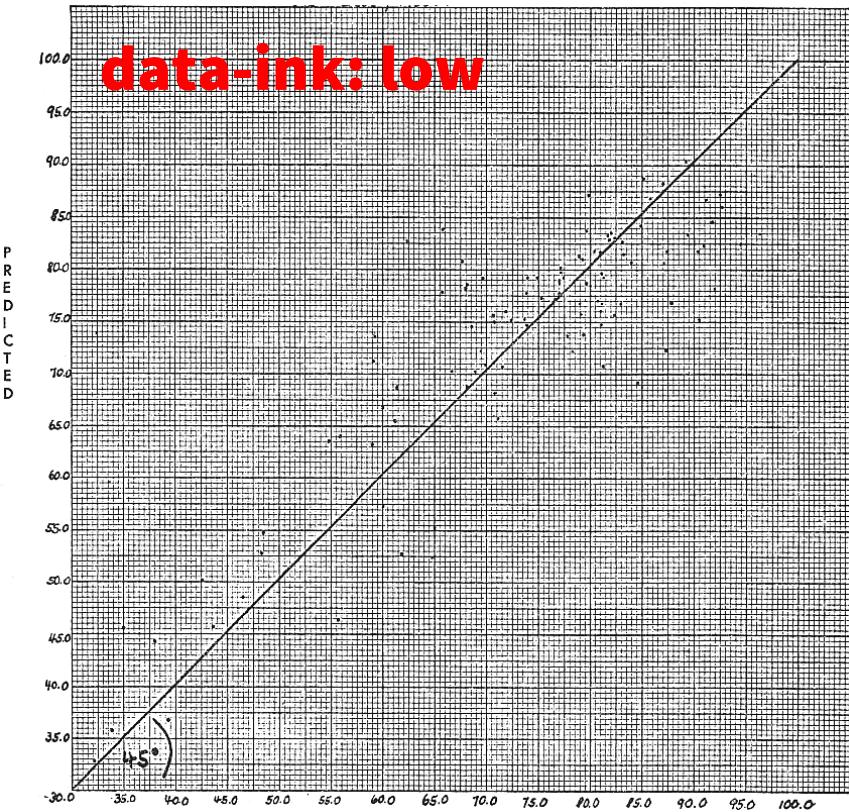
= proportion of a graphic's ink devoted to the non-redundant display of data-information

= $1.0 - \text{proportion of a graphic that can be erased without loss of data-information}$

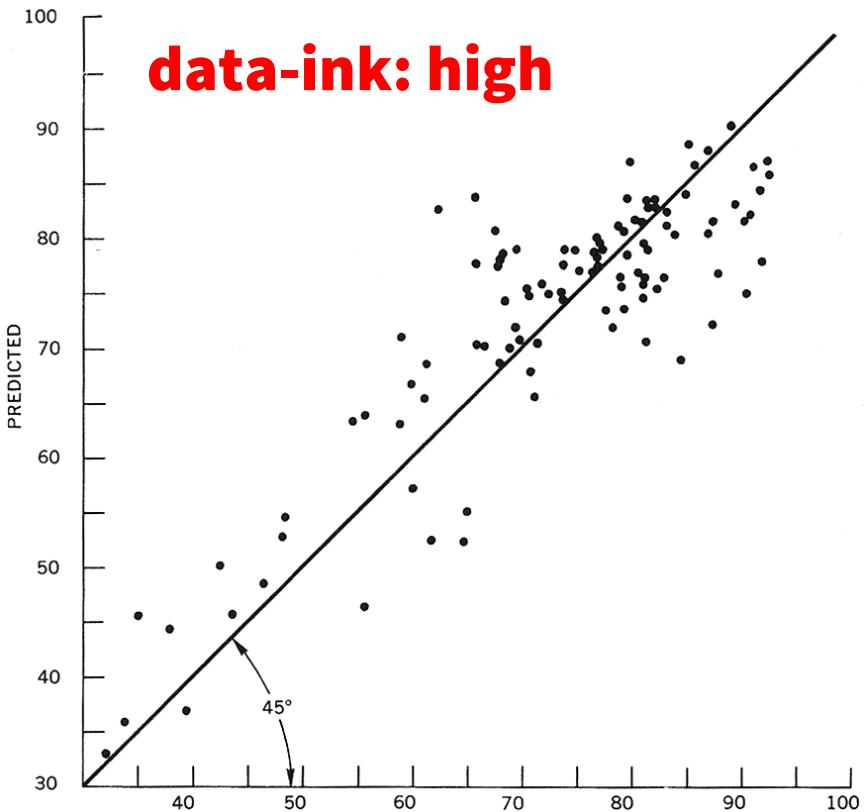


VDQI Example (p93)

- Nothing can be erased without losing information



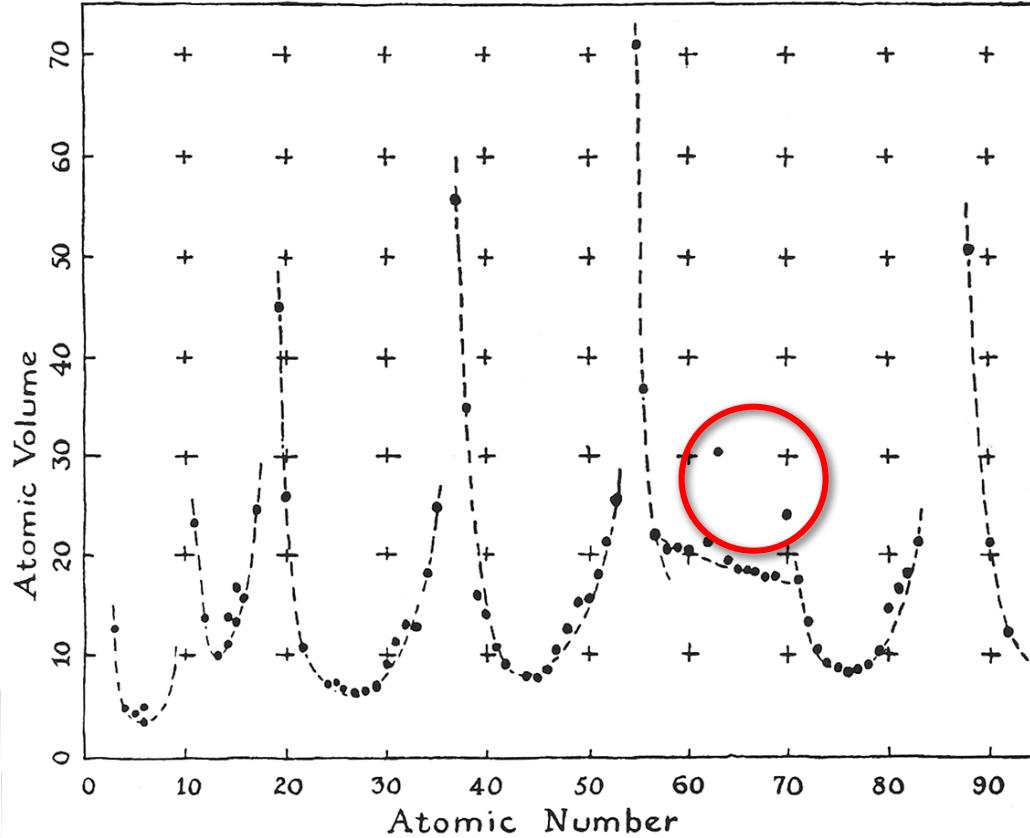
VDQI Example (p94)



Graphic Redesign

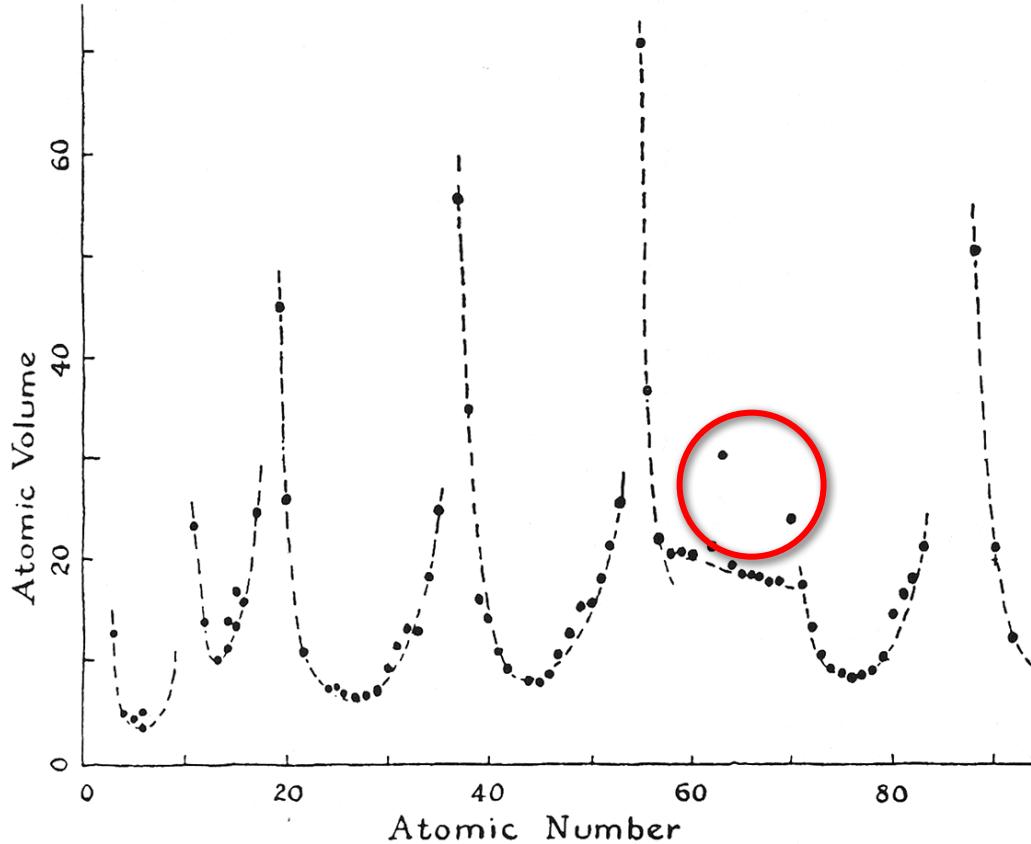
- **Maximize the data-ink ratio, *within reason*.**
- **Erase non-data-ink, *within reason*.**
 - Some ornamentation, axis labels, etc. is okay.
- **Erase redundant data-ink, *within reason*.**
 - Some redundancy is useful.
- **Revise and edit.**

**data-ink:
low**



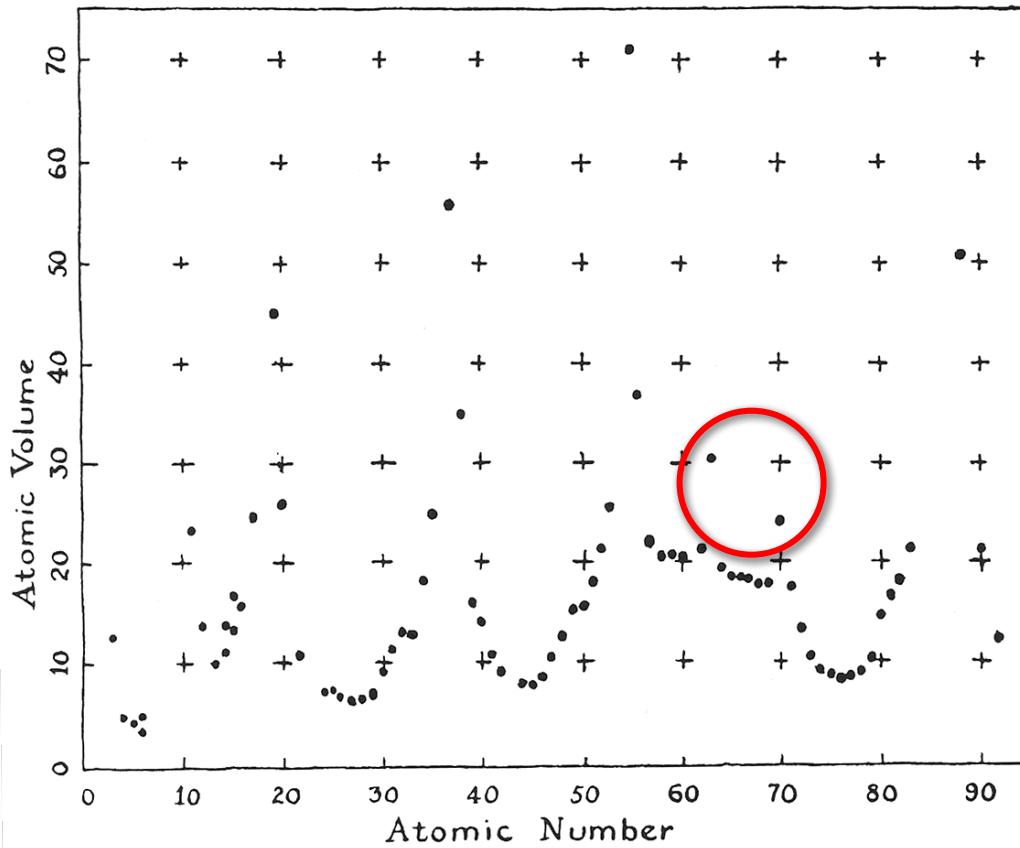
VDQI Example (p102)

remove
grid?

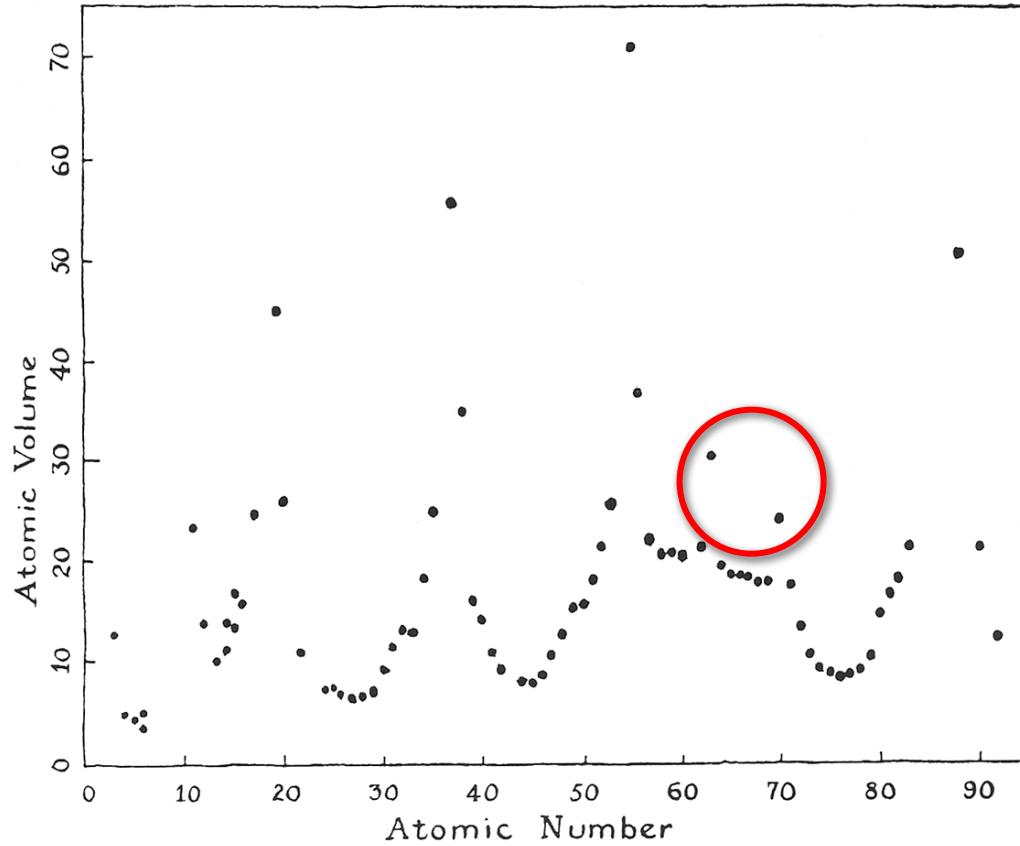


VDQI Example (p102)

remove
lines?

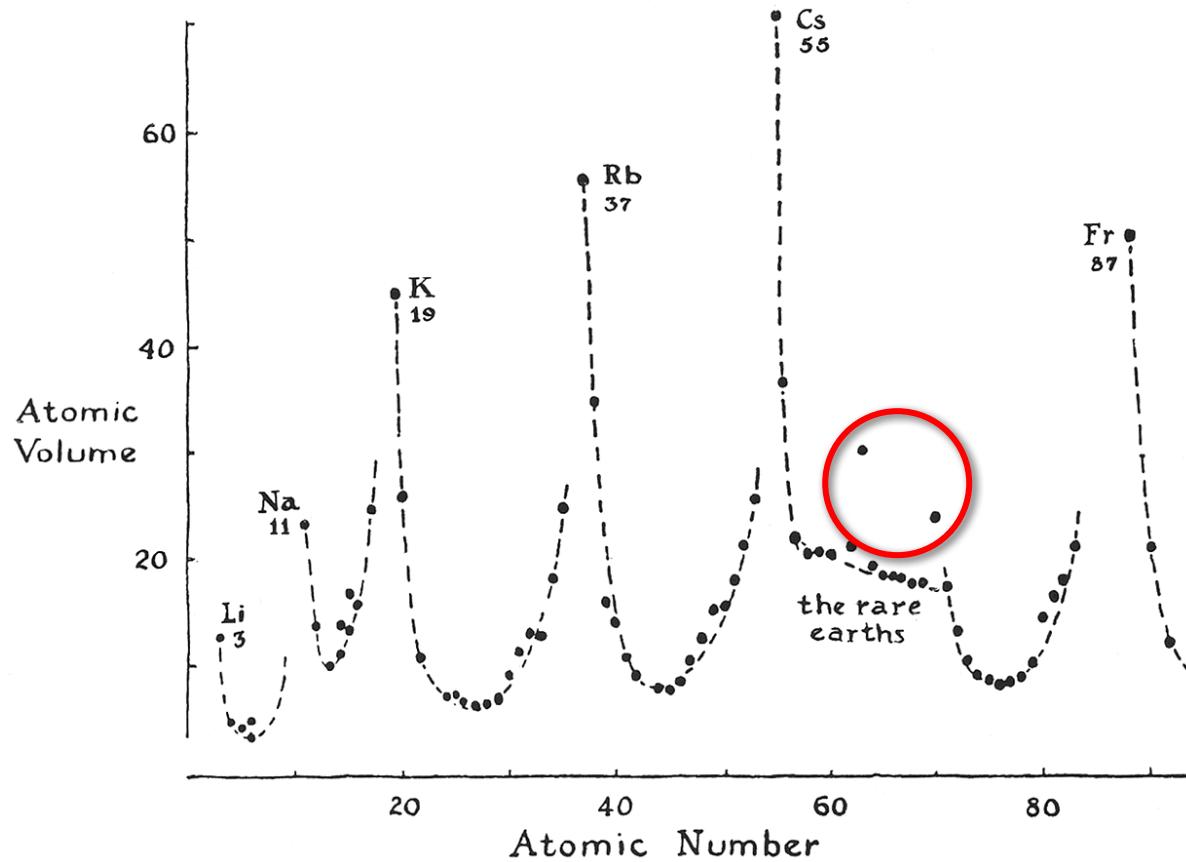


remove
both?



VDQI Example (p102)

final version



VDQI Example (p102)

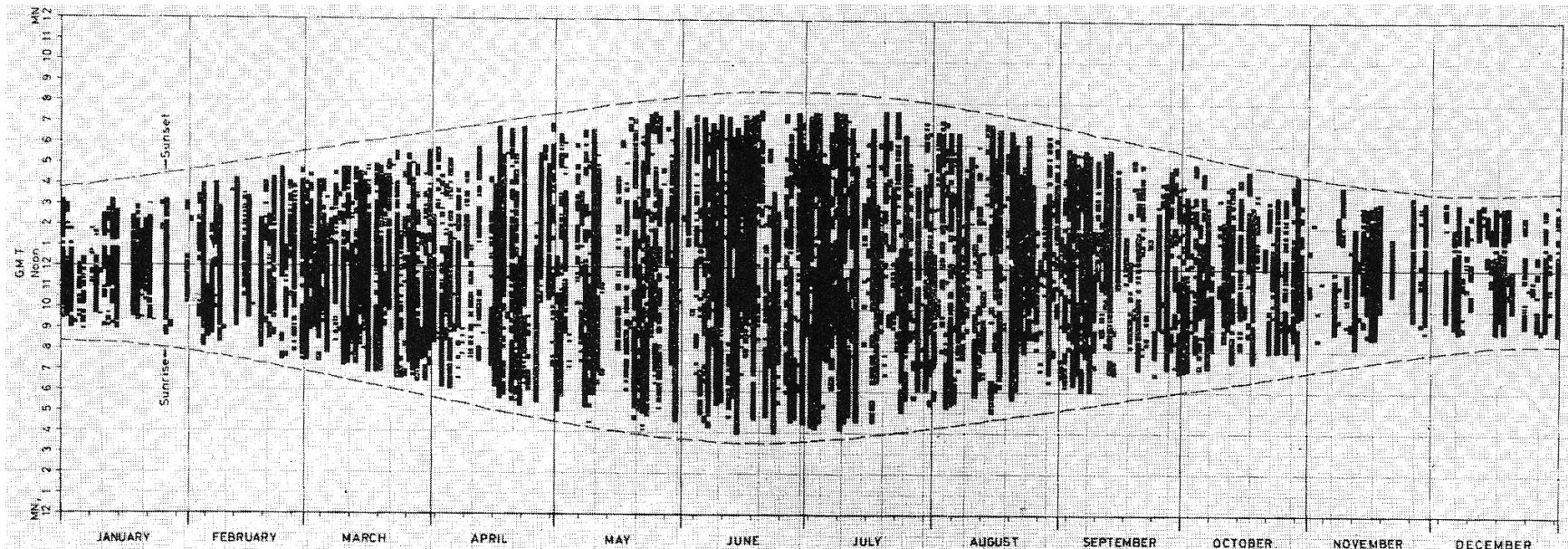
DATA DENSITY

VDQI Chapter 8

Data Density

$$\text{Data Density} = \frac{\text{number of entries in data matrix}}{\text{area of data graphic}}$$

1,000 numbers per square inch



VDQI Example (p165) • Annual Sunshine Record

NO. 1450. STEEL PRODUCTS—NET SHIPMENTS, BY MARKET CLASSES: 1960 TO 1978
 [In thousands of short tons. Comprises carbon, alloy, and stainless steel. "N.e.c." means not elsewhere classified]

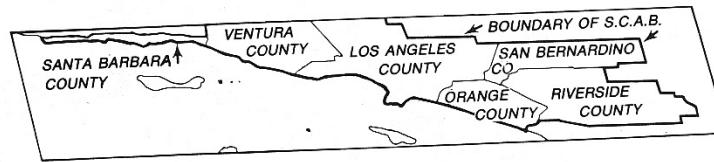
tables /
 matrices
 are
 dense

MARKET CLASS	1960	1965	1970	1973	1974	1975	1976	1977	1978
Total¹	71,149	92,666	90,798	111,430	109,472	79,957	89,447	91,147	97,935
Steel for converting and processing	2,928	3,932	3,443	4,714	4,486	3,255	4,036	3,679	4,612
Independent forgers, n.e.c.	841	1,250	1,048	1,213	1,339	1,098	952	998	1,192
Industrial fasteners ²	1,071	1,234	1,005	1,278	1,331	675	912	848	870
Steel service centers, distributors	11,125	14,813	16,025	20,383	20,400	12,700	14,615	15,346	17,333
Construction, incl. maintenance	9,664	11,836	8,913	10,731	11,360	8,119	7,508	7,553	9,612
Contractors' products	3,602	5,018	4,440	6,459	6,249	3,927	4,502	4,500	3,480
Automotive	14,610	20,123	14,475	23,217	18,928	15,214	21,351	21,490	21,253
Rail transportation	2,525	3,805	3,098	3,228	3,417	3,152	3,056	3,238	3,549
Freight cars, passenger cars,									
locomotives	1,763	2,875	2,005	1,997	2,097	1,794	1,428	1,709	2,188
Rails and all other ³	762	930	1,093	1,231	1,320	1,358	1,628	1,529	1,361
Shipbuilding and marine equip.	622	1,051	859	1,019	1,339	1,413	969	869	845
Aircraft and aerospace	78	94	56	69	79	69	59	63	60
Oil and gas industries	1,759	1,936	3,550	3,405	4,210	4,171	2,653	3,650	4,140
Mining, quarrying, and lumbering	288	392	497	534	644	596	536	486	508
Agricultural, incl. machinery	1,003	1,483	1,126	1,772	1,859	1,429	1,784	1,743	1,805
Machinery, industrial equip., tools	3,958	5,873	5,169	6,351	6,440	5,173	5,180	5,566	5,992
Electrical equipment	2,078	2,985	2,694	3,348	3,242	2,173	2,671	2,639	2,811
Appliances, utensils, and cutlery	1,760	2,179	2,160	2,747	2,412	1,653	1,950	2,129	2,094
Other domestic commercial equip.	1,959	2,179	1,778	1,990	1,941	1,390	1,813	1,846	1,889
Containers, packaging, shipping	6,429	7,331	7,775	7,811	8,218	6,053	6,914	6,714	6,595
Cans and closures	4,976	5,867	6,239	6,070	6,349	4,859	5,290	5,173	4,950
Ordnance and other military	165	289	1,222	918	654	405	219	193	207
Exports (reporting companies only)	2,563	2,078	5,985	3,138	3,961	1,755	1,839	1,076	1,224

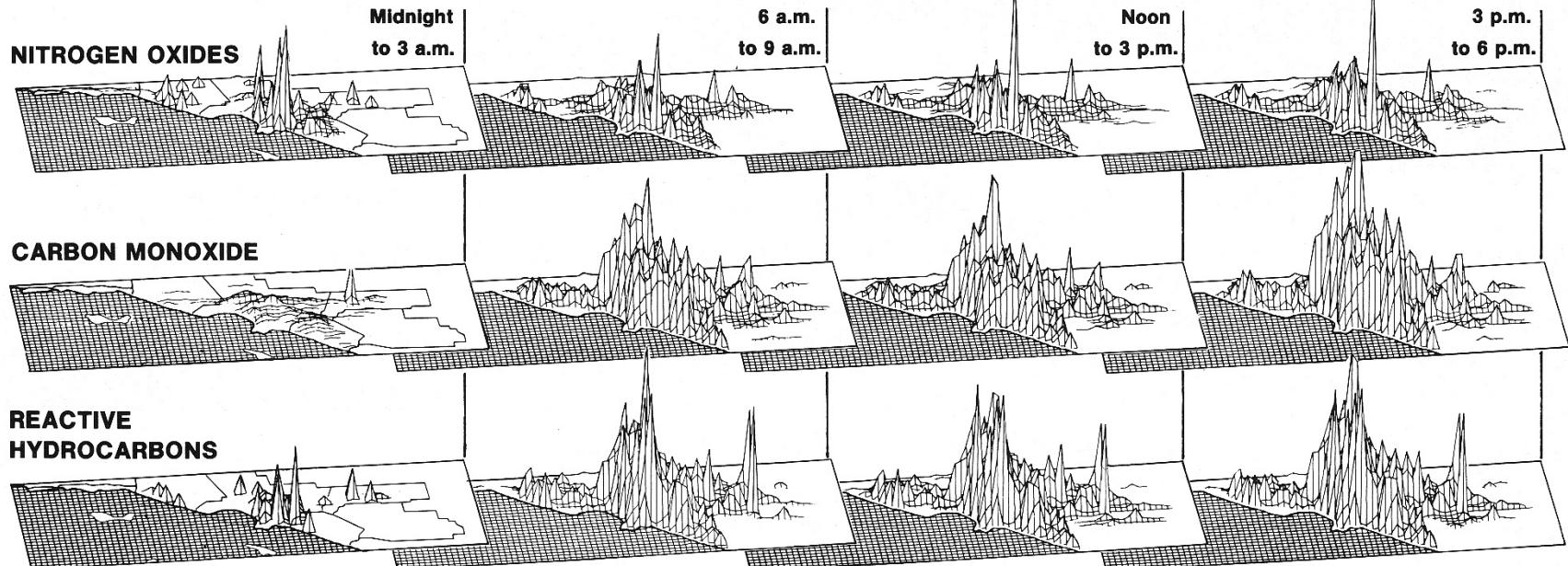
¹ Total includes nonclassified shipments, and, beginning 1970, data include estimates for a relatively small number of companies which report raw steel production but not shipments. ² Bolts, nuts, rivets, and screws.

³ Includes railways, rapid transit systems, railroad rails, trackwork, and equipment.

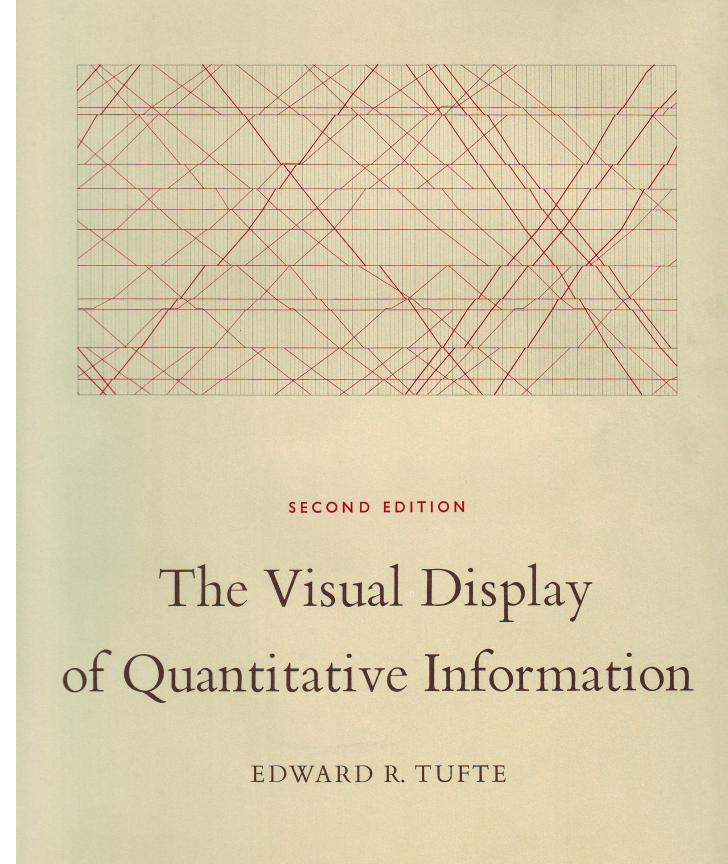
VDQI Example (p161)



small multiples are dense



VDQI Example (p42)





CHANGE THE WORLD FROM HERE