

Tufte's Design Principles



CS 7450 - Information Visualization
October 17, 2016
John Stasko

Please see appropriate
books for missing images

Learning Objectives



- Understand and be able to apply Tufte's principles:
 - Graphical integrity (baselines, size coding)
 - Maximize data-ink ratio
 - Avoid chartjunk
 - Macro/micro-readings
 - Small multiples
 - Minimize/unite grids, labeling, legends
 - Appropriate applications of color

Today's Agenda

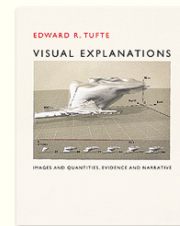
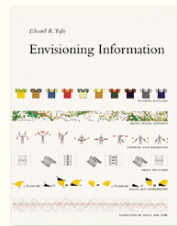
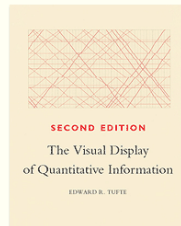


Edward Tufte has written seven books, including *Visual Explanations*, *Envisioning Information*, *The Visual Display of Quantitative Information*, and *Data Analysis for Politics and Policy*. He writes, designs, and self-publishes his books on analytical design, which have received more than 40 awards for content and design. He is Professor Emeritus at Yale University, where he taught courses in statistical evidence, information design, and interface design. His current work includes landscape sculpture, printmaking, video and a new book.

This website describes Edward Tufte's books, one-day course, and artwork. For further information, call Graphics Press at 203 272-9187, or fax 203 272-8600, or [email](mailto:et@graphicspress.com).

For a moderated forum on analytical design, go to [ASK E.T.](http://www.edwardtufte.com/ask-et/)

BOOKS



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Graphical Excellence



- Principles
 - Graphical excellence is the well-designed presentation of interesting data---a matter of *substance*, of *statistics*, and of *design*
 - Graphical excellence consists of complex ideas communicated with clarity, precision and efficiency

According to Tufte

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Graphical Excellence



- Principles
 - Graphical excellence is that which gives to the viewer the greatest number of ideas in the shortest time with the least ink in the smallest space
 - Graphical excellence is nearly always multivariate
 - And graphical excellence requires telling the truth about the data

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Leveraging Human Capabilities



- Data graphics should complement what humans do well

“We thrive in information-thick worlds because of our marvelous and everyday capacities to select, edit, single out, focus, organize, condense, reduce, boil down, choose, categorize, catalog, classify, list, abstract, scan, look over, sort, integrate, blend, inspect, filter, lump, skip, smooth, chunk, average, approximate, cluster, aggregate, outline, summarize, itemize, review, dip into, flop through, browse, glance into, leaf through, skim, refine, enumerate, glean, synopsisize, winnow the wheat from the chaff, and separate the sheep from the goats.” **Vol.2, page 50**

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Summary



- 1. Tell the truth
 - Graphical integrity
- 2. Do it effectively with clarity, precision...
 - Design aesthetics

Let's look at each of these

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1. Graphical Integrity



- Your graphic should tell the truth about your data

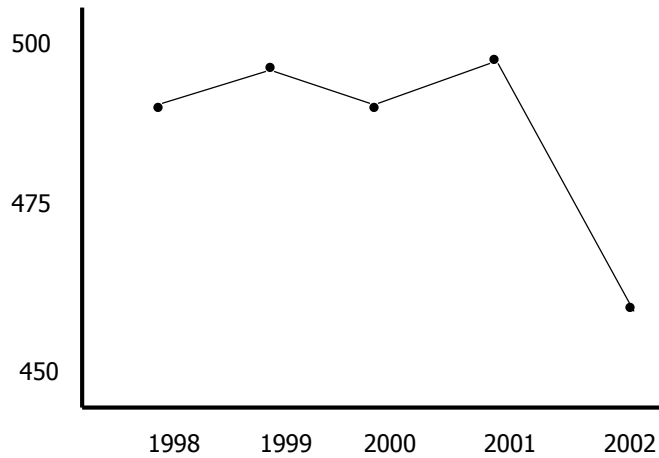
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Example

Stock market crash?

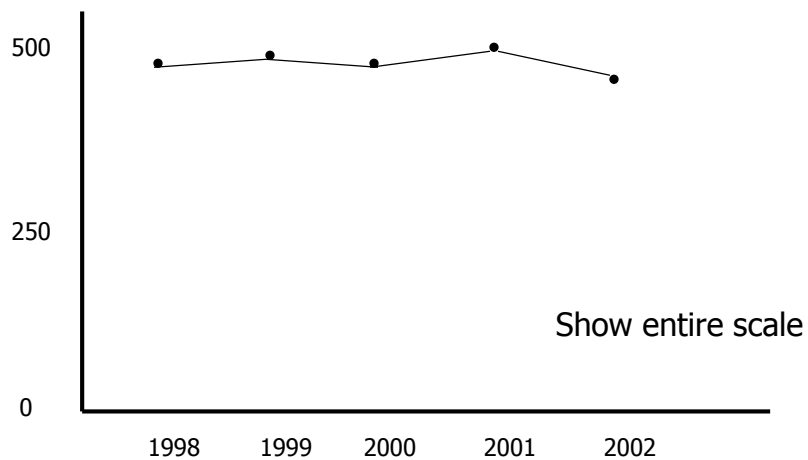


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Example

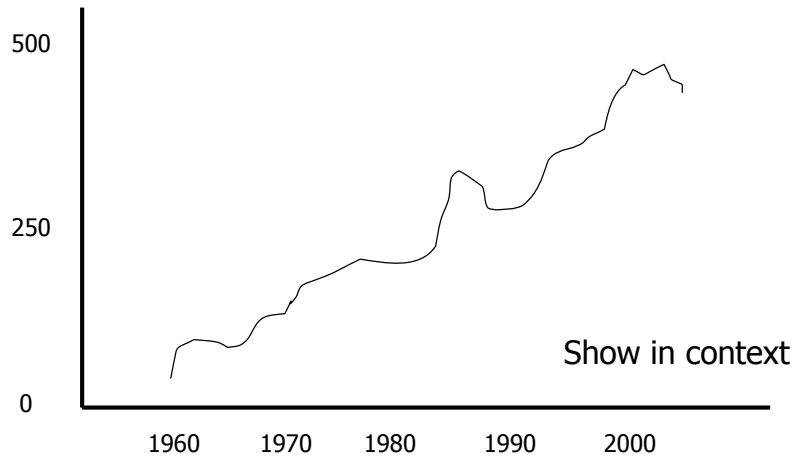


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Example



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Chart Integrity



- Where's baseline?
- What's scale?
- What's context?

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Where's 0?
Note middle '70

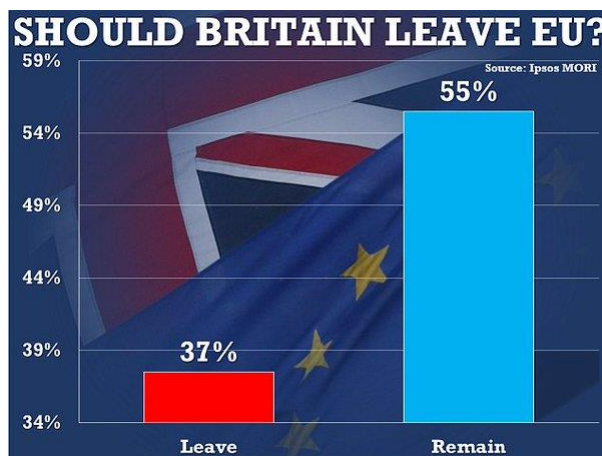


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Huge Difference?



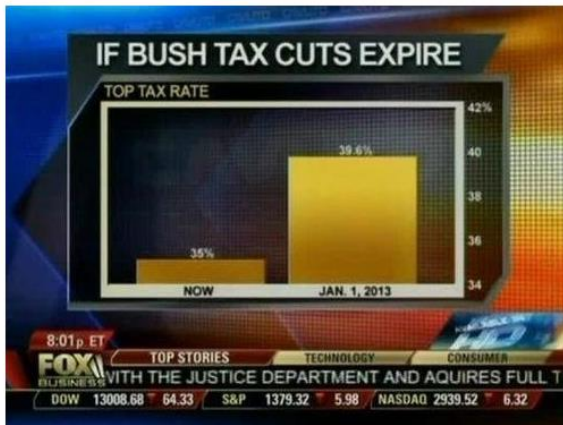
Compare area of
right bar to that
of the left bar

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Huge Difference?



Compare area of right bar to that of the left bar

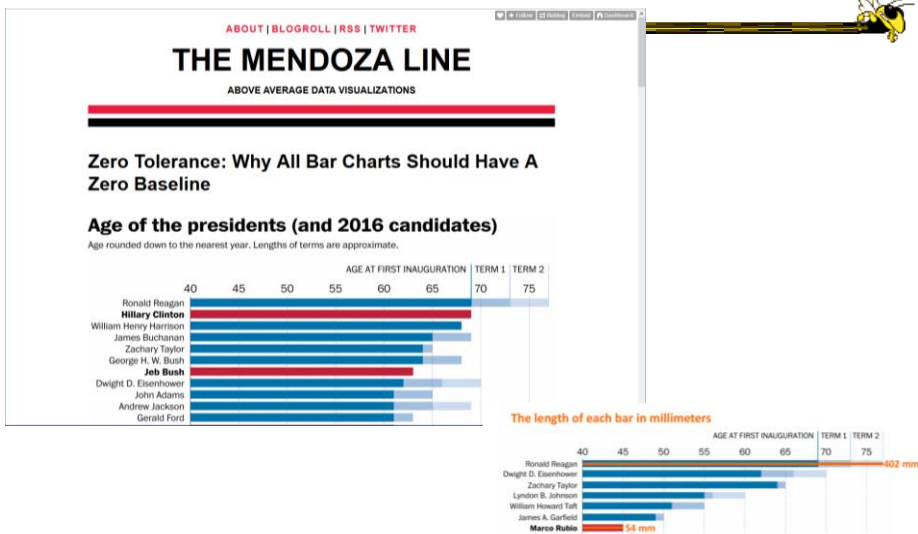
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<http://themendozalive.org/post/118146423986/zero-tolerance-why-all-bar-charts-should-have-a>

Baseline?



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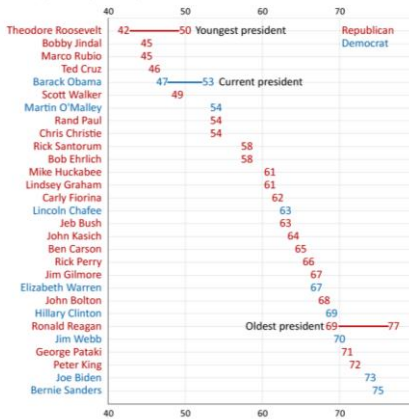
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Suggested Redo



How Old Are The People Running For President In 2016?

The chart shows how old each candidate would be at his or her inauguration. The age of each president spans from the year of his inauguration to the last year of his presidency.



Suggests using dot plots when there is a big range down to zero

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What's being compared?

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Scale?

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Scale?

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Great work!

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Ahhhh

Show the context

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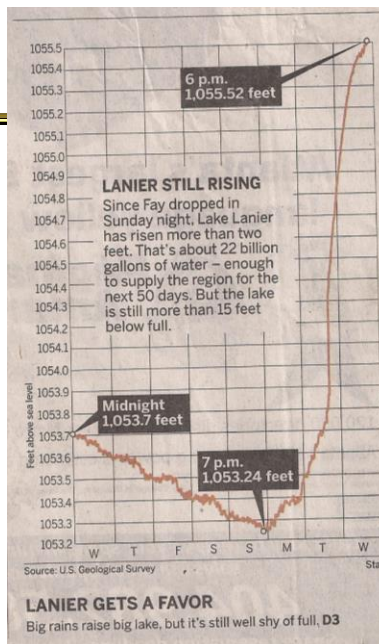
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Local Example

A huge rise?

Atlanta Journal Constitution
Summer '08



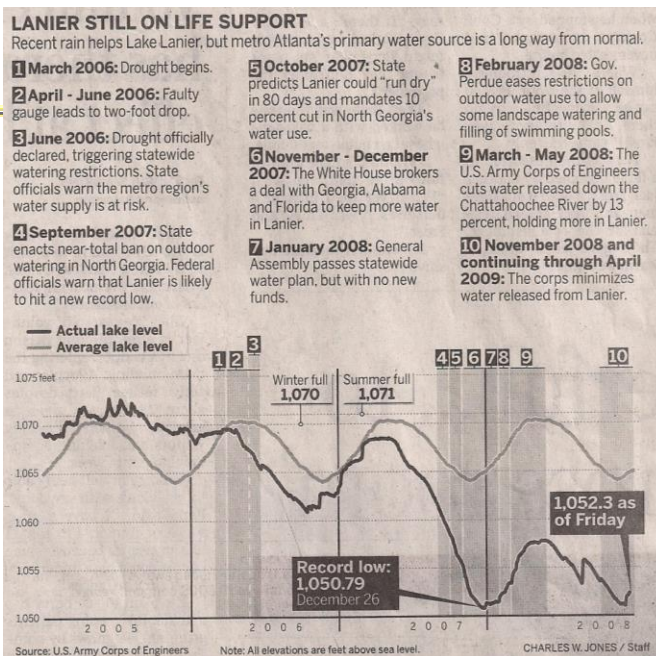
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More of the data

Atlanta Journal Constitution
Dec. '08

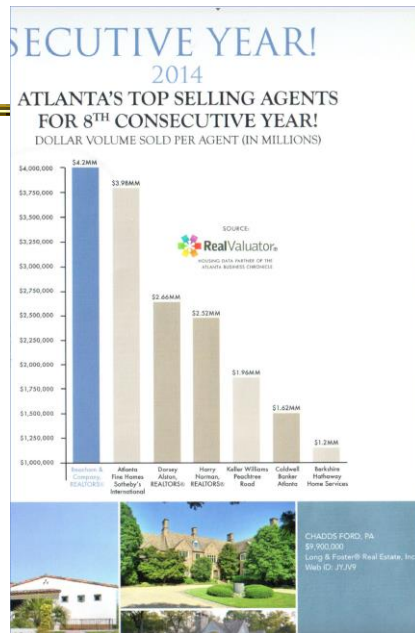


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Baselines & heights?



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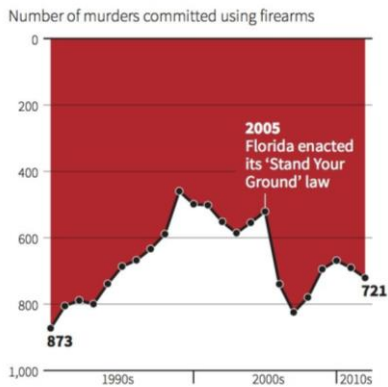
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<http://www.businessinsider.com/gun-deaths-in-florida-increased-with-stand-your-ground-2014-2>

A Redesign



Gun deaths in Florida

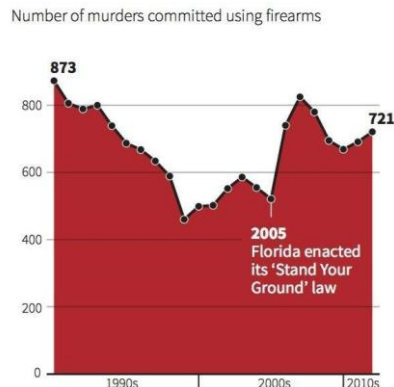


Source: Florida Department of Law Enforcement
C. Chan 16/02/2014



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Gun deaths in Florida



Source: Florida Department of Law Enforcement

P.A. Pedone and Pedone

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Watch Size Coding



- Height/width vs. area vs. volume

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area = value?

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volume = value?

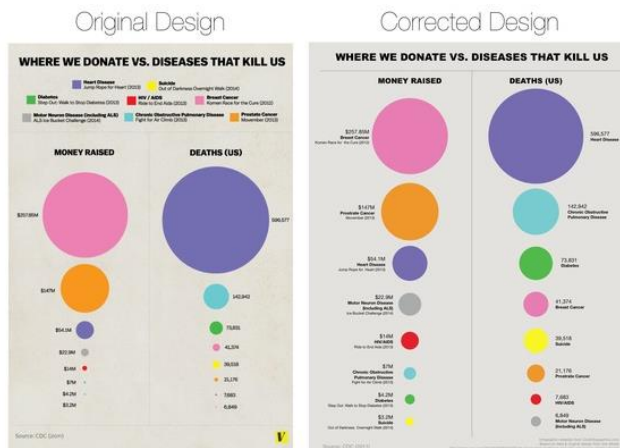
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http://www.huffingtonpost.com/randy-krum/false-visualizations-when_b_5736106.html

Circle Width vs. Area



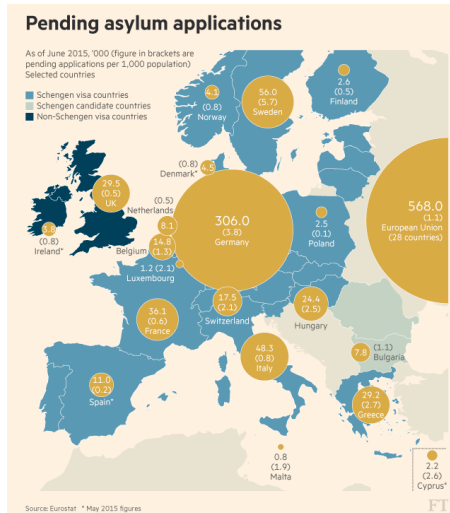
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http://www.ft.com/intl/cms/s/2/7f7e0d28-5225-11e5-8642-453585f2cfd.html

Areas? Not Sure



Europe

Home UK* World* Companies* Markets* Global Economy* List* Comment*

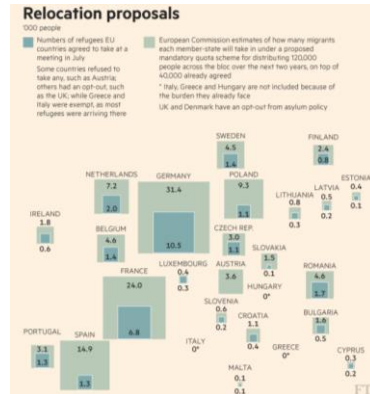
Asia* Asia Pacific* Europe* Latin America* Middle East & North Africa* UK* US & Canada*

Last updated September 4, 2015 12:10 pm

Migrant crisis explained in numbers

Share Author alerts Print Clip

The EU is struggling to respond to a surge of desperate migrants, thousands of whom have perished in their attempts to seek a better life in Europe. Where are they going and where are they coming from?



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Measuring Misrepresentation



- Visual attribute value should be directly proportional to data attribute value

$$\text{Lie factor} = \frac{\text{Size of effect shown in graphic}}{\text{Size of effect in data}}$$

p.62 9.4 = $\frac{4280}{454}$
oil barrels

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2. Design Aesthetics



- Set of principles to help guide designers

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Design Principles



- Maximize data-ink ratio

$$\text{Data ink ratio} = \frac{\text{Data ink}}{\text{Total ink used in graphic}}$$

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

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Good

Bad

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Outstanding

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More...



- Above all else, show the data
- Maximize the data-ink ratio
- Erase non-data-ink
- Erase redundant data-ink
- Revise and edit

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More...



- Maximize data density

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

Quote ...

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Maximize Data Density



“Data-rich designs give a context and credibility to statistical evidence. Low-information designs are suspect: what is left out, what is hidden, why are we shown so little? High-density graphics help us to compare parts of the data by displaying much information within the view of the eye: we look at one page at a time and the more on the page, the more effective and comparative our eye can be. The principle, then, is:

Maximize data density and the size of the data matrix, within reason.”

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Redesign charts



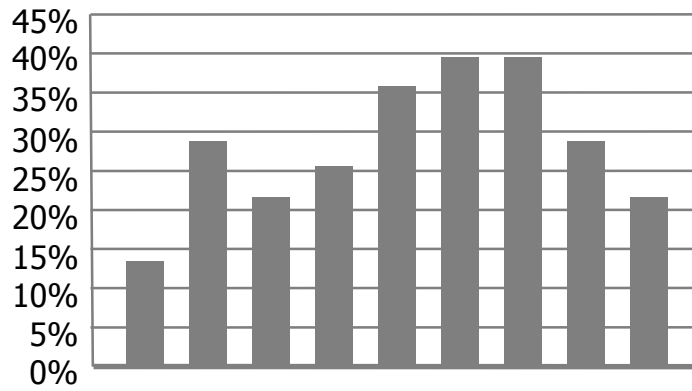
- Bar chart, scatter plot, box plot

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Bar chart

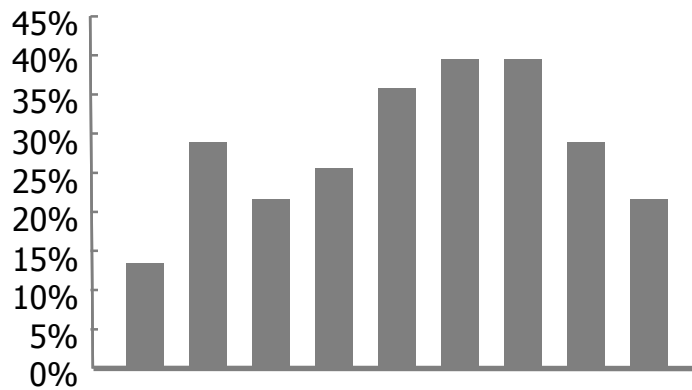


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Bar chart

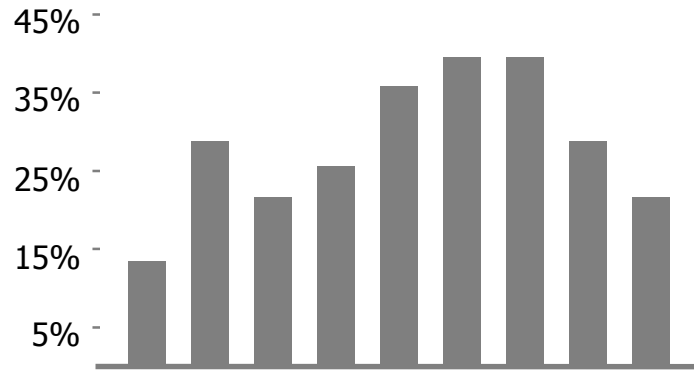


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Bar chart

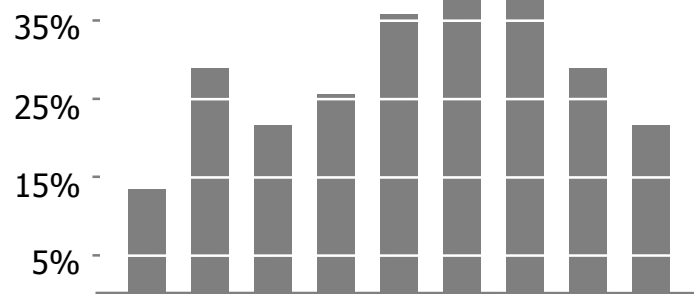


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Bar chart

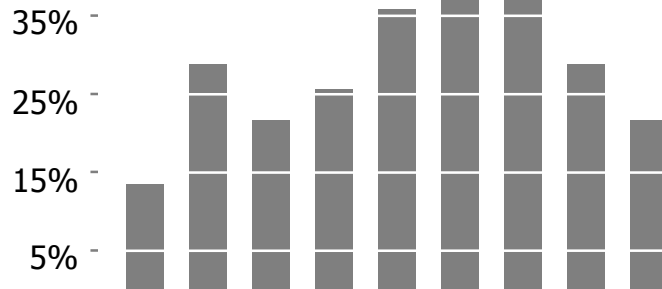


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Bar chart

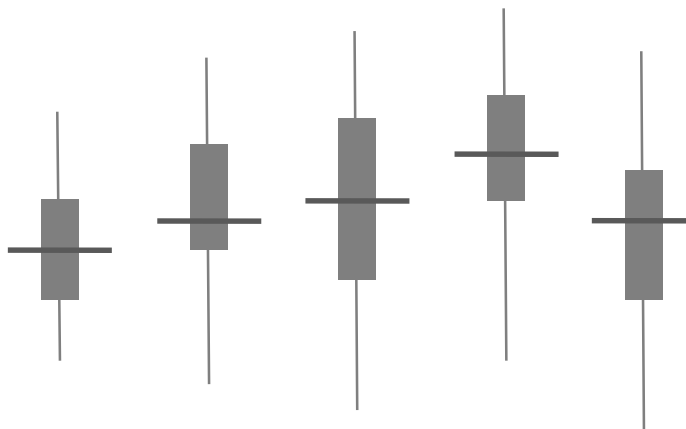


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Box plot

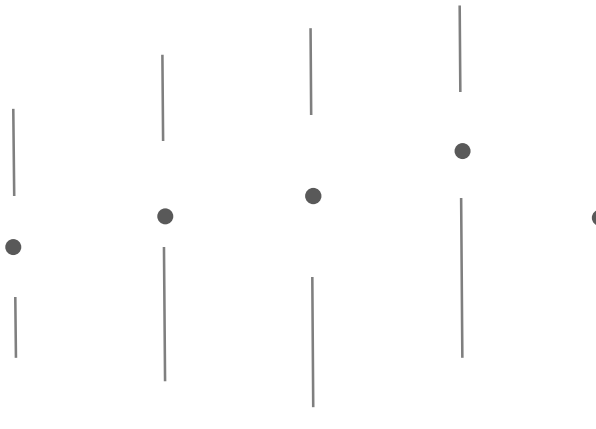


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Box plot

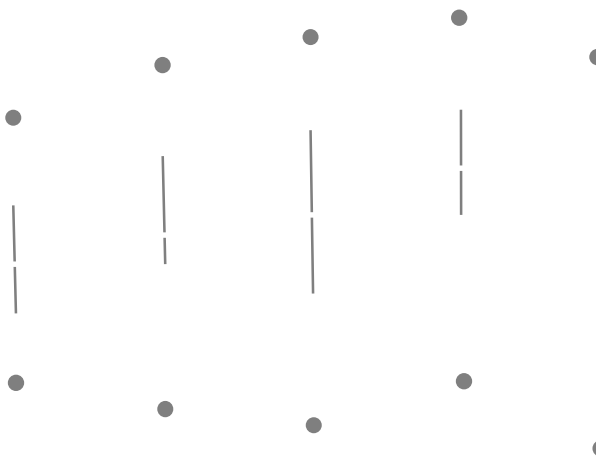


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Box plot

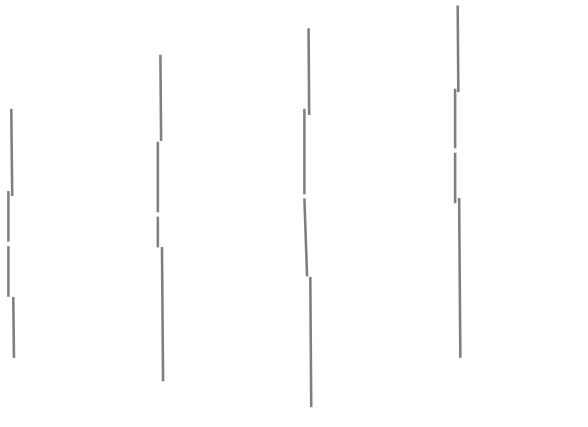


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Box plot

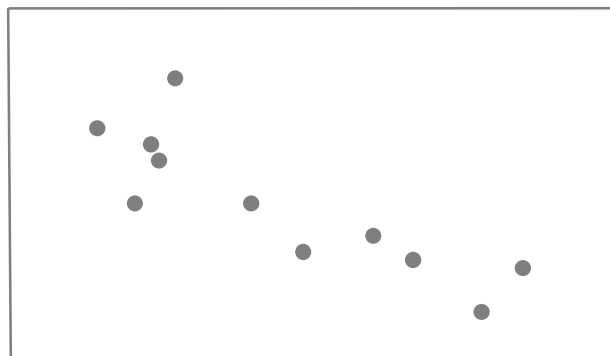


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Scatter plot

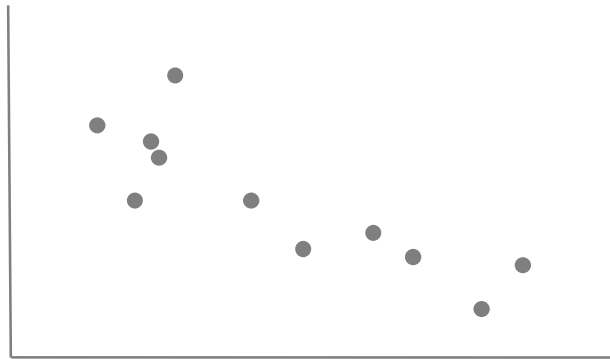


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Scatter plot

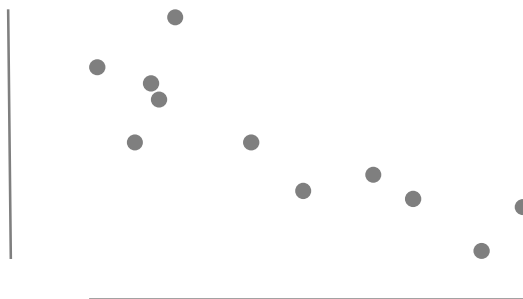


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Scatter plot

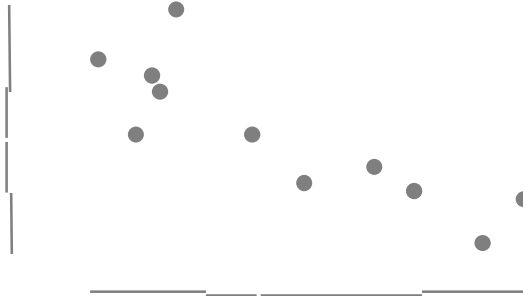


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Scatter plot



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Design Principles



- **Avoid chartjunk**
 - Extraneous visual elements that detract from message

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Vol 2, p.34



A classic

Diamonds Were A
Girl's Best Friend

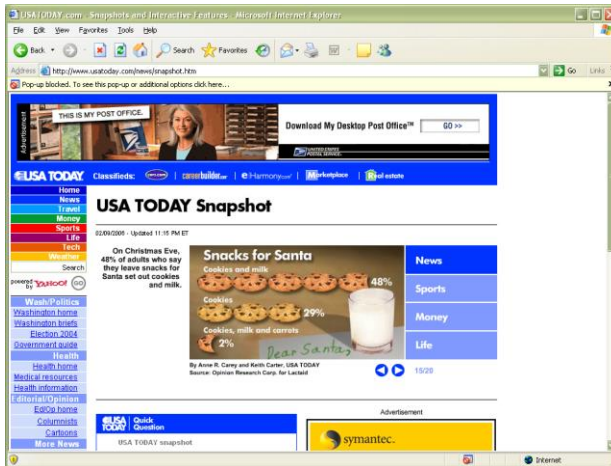
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USA Today

<http://www.usatoday.com/news/snapshot.htm>



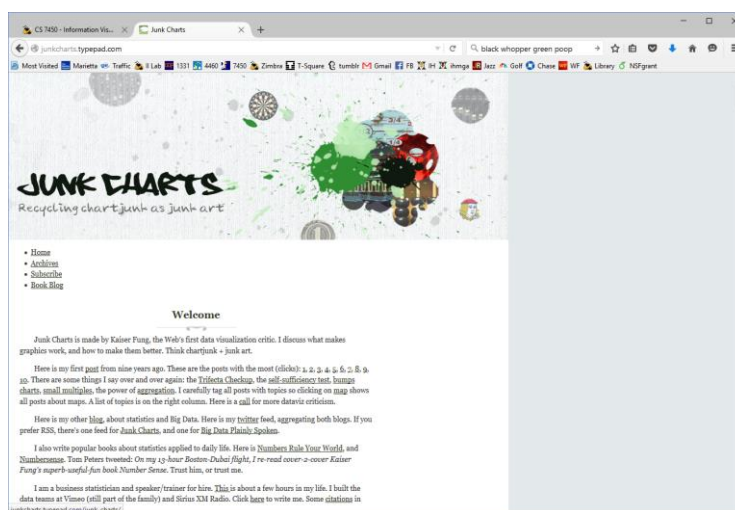
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Junk Charts Blog

<http://junkcharts.typepad.com/>



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More Thoughts



Great narrative: Vol.2, bottom page 33-34

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Rethink That?



CHI 2010, Graphics April 10-15, 2010, Atlanta, GA, USA

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

Scott Bateman, Regan L. Masarik, Carl Gutwin, Aaron Green, David McDias, Christopher Brooks
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ABSTRACT
Guidelines for designing information charts often state that the presenter should include their goal – visual embellishments that are not essential to understanding the data. In contrast, some propose chart designers strip the presented data to denoted and enhance memory, citing the existence of a mental list concept in memory as justification for underlining as has been proposed, and whether the visual embellishment may have other benefits. To investigate these issues, we conducted an experiment that compared embellished charts with plain ones, and measured both comprehension accuracy and long-term recall. We found that people's accuracy in describing the embellished charts was no worse than the plain charts, and that their recall after a two-to-three-week gap was significantly better. Although we are cautious about recommending that all charts be presented in this style, our results question some of the premises of the minimalist approach to chart design.

Author keywords:
Chart, information visualization, imagery, memorability.

ACM Classification Keywords:
H.1.2. Information interfaces and presentation (e.g., HCI):

Visualizations.

General Terms:
Design, Human Factors

INTRODUCTION
Many experts in the area of chart design, such as Edward Tufte, criticize the inclusion of visual embellishments in charts and graphics, citing guidelines for good chart design which suggest that the addition of chart junk obscures and other kinds of non-essential imagery, in a chart can make comprehension more difficult and slow down readers from the data [22]. This minimalist perspective advocates plain and simple charts that maximize the proportion of data ink – or the ink to the chart used to represent data.

Researchers in media design in both ranges of all or part of the work the period of computer use in general within the period that spans to our work in the field of graphics and visualization. We have been interested in the effects of visual embellishment on memory, in particular, as well as on other aspects of memory, such as comprehension and recall. We have been particularly interested in the effects of visual embellishment on memory, in particular, as well as on other aspects of memory, such as comprehension and recall. We have been particularly interested in the effects of visual embellishment on memory, in particular, as well as on other aspects of memory, such as comprehension and recall.

CHI 2010, April 10-15, 2010, Atlanta, Georgia, USA.
Copyright 2010 ACM 978-1-4555-2860-6/10/04...\$5.00.

Designs that minimize problems, many designers include a wide variety of visual embellishments in their charts, from small decorations to large images and visual backgrounds. Our work focuses on the presence of visual embellishments in charts in the popular press (Figure 1), whose work regularly incorporates some visual imagery into the design of the chart (Figure 1, Figure 2).

EMBELLISHED CHARTS



Figure 1. A chart by Johnson [2] (above), and a plain version.

These kinds of charts appear regularly in many mass-media publications, and the widespread use of embellished designs raises questions about whether the minimalist position on chart design is really the better approach. Two issues in particular are raised: first, whether visual embellishments do in fact cause comprehension problems, and second, whether the embellishments may provide additional information that is valuable for the reader. For example, the added visual imagery in a Johnson-style chart could draw

Compared plain charts to “embellished” charts

Found that the embellished charts were just as good on interpretation accuracy and were recalled better weeks later

Participants also preferred the embellished ones

Some caveats:

- Very simple data
- Very plain plain charts
- Each chart/data is different

My take: It's all about purpose

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Memorability



208 IEEE TRANSACTIONS ON VISUALIZATION AND COMPUTER GRAPHICS, VOL. 19, NO. 12, DECEMBER 2013

What Makes a Visualization Memorable?

Michelle A. Borris, Student Member, IEEE, Anissa A. Vu, Zoya Djivanli, Philip Itoke, Student Member, IEEE, Shaohua Turkkanavli, Aude Oliva, and Hanspeter Pfister, Senior Member, IEEE

Fig. 1. Left: The top twelve (overall most memorable) visualizations from our experiment (most to least memorable from top left to bottom right). Middle: The six twelve most memorable visualizations from our experiment (most to least memorable from top left to bottom right). Right: The twelve least memorable visualizations from our experiment (most to least memorable from top left to bottom right).

Abstract—An ongoing debate in the Visualization community concerns the role that visualization type plays in data understanding. In better capturing understanding and memorability are intertwined. In a 20-day research lab, we able to link memorability (short recall and effectiveness), how we ask, “What makes a visualization memorable?” We ran the largest scale visualization study to date using 2,273 unique experimental conditions, categorized with visualization type (e.g., bar chart, pie chart, etc.), selected from over 1000 charts, government reports, scientific journals, and geographic sources. Each visualization was annotated with additional attributes, including whether the data was unique and novel, and the number of data points. Using Ananova, Mechanical Turk, we collected memorability scores for hundreds of these visualizations. We discovered that memorability is correlated to which visualization type was used, the number of data points, and whether results (e.g., attributes like color and the inclusion of a human recognizable object enhance memorability) and how inclusive results (e.g., common graphs are less memorable than unique visualization types). Altogether our findings suggest that quantifying memorability is a general metric of the utility of information, an essential step towards determining how to design effective visualizations.

Index Terms—Visualization taxonomy, information visualization, memorability

1 INTRODUCTION

The Visualization community has recently witnessed a divide over the value and impact of memorability. Some researchers and practitioners (e.g., “short-term”) focus on the immediate recall and effectiveness of a visualization (e.g., “short-term”), while others (e.g., “long-term”) focus on the long-term recall and effectiveness of a visualization (e.g., “long-term”).

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For more information on this publication, please contact the author at borris@fas.harvard.edu.

Published by the IEEE Computer Society.

Mechanical Turk study

- Color and human recognizable objects enhance memorability
- Common graphs are less memorable than unique visualization types

But memorability is only one dimension of utility ... and perhaps not one of the most important ones

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Design Principles



- Utilize multifunctioning graphical elements (macro/micro readings)
 - Graphical elements that convey data information and a design function

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US Army Divisions
going to France in
WW I

Leonard P. Ayres
The War with Germany
1919

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Michel E. Turgot
Louis Bretz

Plan de Paris
1739

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Manhattan 1989
Manhattan Map Company



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Viet Nam Memorial
in Washington D.C.

Maya Ying Lin

58,000+ dead soldiers

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Names listed
chronologically by death

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Design Principles



- **Use small multiples**
 - Repeat visually similar graphical elements nearby rather than spreading far apart

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23 hours of
LA air pollution

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Chromosomes of
man, chimpanzee,
gorilla & orangutan

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Consumer
Reports

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NY Trains

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How to draw letters

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Calligraphy

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More Recent Additions



Sparklines: theory and practice

Theory of sparklines (small, intense, simple datawords) along with many practical examples of recent sparkline developments. From Edward Tufte's book *Beautiful Evidence*.

-- Edward Tufte, May 27, 2004

Sparklines

Small, repeated graphics (frequently line graphs)

Sparklines: theory and practice

Theory of sparklines (small, intense, simple datawords) along with many practical examples of recent sparkline developments. Excerpts from Edward Tufte, *Beautiful Evidence*. New examples or helpful comments much appreciated.

ET

Sparklines: Intense, Simple, Word-Sized Graphics

THE most common data display is a noun followed by some numbers. For example, a medical patient's current level of glucose is typically reported in a clinical record as a word and number.

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Sparkline Examples



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Design Principles



- Show mechanism, process, dynamics, and causality
 - Cause and effect are key
 - Make graphic exhibit causality

Space shuttle case we discussed first day

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Vol 3, p. 144



Washington Post

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Design Principles



- **Escape flatland**
 - Data is multivariate
 - Doesn't necessarily mean 3D projection

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Vol 2, p. 12



Guide for visitors to Ise Shrine, Japan

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Vol 2, p. 24



Timetable for Java railroad line

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Vol 3, p. 90

Music history



Steve Chapple and Reebee Garofalo

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Design Principles



- Utilize layering and separation
 - 1+1 = 3 or more
 - Good or bad

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Vol 2, p. 54

IBM Series III Copier



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Vol 2, p. 61



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Design Principles



- Utilize narratives of space and time
 - Tell a story of position and chronology through visual elements

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Vol 1, p.43 & Vol 2, p 110



Life of a beetle

L. Hugh Newman

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Vol 2, p. 102



Czech air schedule

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Vol 2, p. 103



China railway
timetable

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Design Principles



- **Content is king**
 - Quality, relevance and integrity of the content is fundamental
 - What's the analysis task? Make the visual design reflect that
 - Integrate text, chart, graphic, map into a coherent narrative

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Graph and Chart Tips



- Avoid separate legends and keys -- Just have that information in the graphic
- Make grids, labeling, etc., very faint so that they recede into background

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Vol 2, p. 54

New Jersey Transit



Before

After

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Vol 2, p. 63



Before

After

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Vol 3, p. 74



Before

After

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Using Color Effectively



- “The often scant benefits derived from coloring data indicate that even putting a good color in a good place is a complex matter. Indeed, so difficult and subtle that avoiding catastrophe becomes the first principle in bringing color to information: *Above all, do no harm.*”

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Proper Color Use



- To label
- To measure
- To represent or imitate reality
- To enliven or decorate

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Examples



- The bad...

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Vol 1, p. 153



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Description



"..despite its clever and multifunctioning data measure, formed by crossing two four-colored grids, this is a puzzle graphic. Deployed here, in a feat of technological virtuosity, are 16 shades of color spread on 3,056 counties, a monument to a sophisticated computer graphics system. But it is surely a graphic experienced verbally not visually. Over and over, the viewers must run little phrases through their minds, trying to maintain the right pattern of words to make sense of the visual montage: "Now let's see, purple represents counties where there are both high levels of male cardiovascular disease mortality and 11.6 to 56.0 percent of the households have more than 1.01 persons per room..."

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Vol 2, p. 82



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Vol 2, p. 88



"Color's multidimensionality can also enliven and inform what users must face at computer terminals, although some color applied to display screens has made what should be a straight-forward tool into something that looks like a grim parody of a video game."

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Vol 3, p. 77



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Examples



- The good...

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Vol 2, p. 91 & Vol 3, p. 76



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Vol 2, p. 80



Swiss Mountain Map

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Guides for Enhancing Visual Quality



- Attractive displays of statistical info
 - have a properly chosen format and design
 - use words, numbers and drawing together
 - reflect a balance, a proportion, a sense of relevant scale
 - display an accessible complexity of detail
 - often have a narrative quality, a story to tell about the data
 - are drawn in a professional manner, with the technical details of production done with care
 - avoid content-free decoration, including chartjunk

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Information Overload



What about confusing clutter? Information overload?
 Doesn't data have to "boiled down" and "simplified"?
 These common questions miss the point, for the quantity of detail is an issue completely separate from the difficulty of reading. *Clutter and confusion are failures of design, not attributes of information.* Often the less complex and less subtle the line, the more ambiguous and less interesting is the reading. Stripping the detail out of data is a style based on personal preference and fashion, considerations utterly indifferent to substantive content. **Vol. 2, p. 51**

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Minard graphic



size of army
 direction

latitude
 longitude

temperature
 date

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Graphical Displays Should



- Show the data
- Induce the viewer to think about substance rather than about methodology, graphic design the technology of graphic production, or something else
- Avoid distorting what the data have to say
- Present many numbers in a small space
- Make large data sets coherent
- Encourage the eye to compare different pieces of data
- Reveal the data at several levels of detail, from a broad overview to the fine structure
- Serve a reasonably clear purpose: description, exploration, tabulation, or decoration
- Be closely integrated with statistical and verbal descriptions of a data set

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Website & Seminar



The Work of Edward Tufte and Graphics Press - Mozilla Firefox

File Edit View History Bookmarks Tools Help

http://www.edwardtufte.com/tufte/

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PRESENTING DATA AND INFORMATION:
A ONE-DAY COURSE TAUGHT BY EDWARD TUFTTE

Topics covered in this one-day course include:

- fundamental strategies of analytical design
- evaluating evidence used in presentations
- statistical data tables, graphics, and semi-graphics
- business, scientific, research, and financial presentations
- complexity and clarity
- effective presentations: on paper and in person
- interface design
- use of PowerPoint, video, overheads, and handouts
- multi-media, internet, and websites
- credibility of presentations
- animation and scientific visualizations
- many practical examples

Durham, North Carolina [March 9, 2009](#)
[March 10, 2009](#)

Atlanta, Georgia [March 12, 2009](#)
[March 13, 2009](#)

Arlington, Virginia [April 6, 2009](#)
[April 7, 2009](#)
[April 8, 2009](#)

Seattle, Washington [April 28, 2009](#)
[April 29, 2009](#)

Portland, Oregon [May 1, 2009](#)

"One visionary day...the insights of this class lead to new levels of understanding both for creators and viewers of visual displays." WIREP

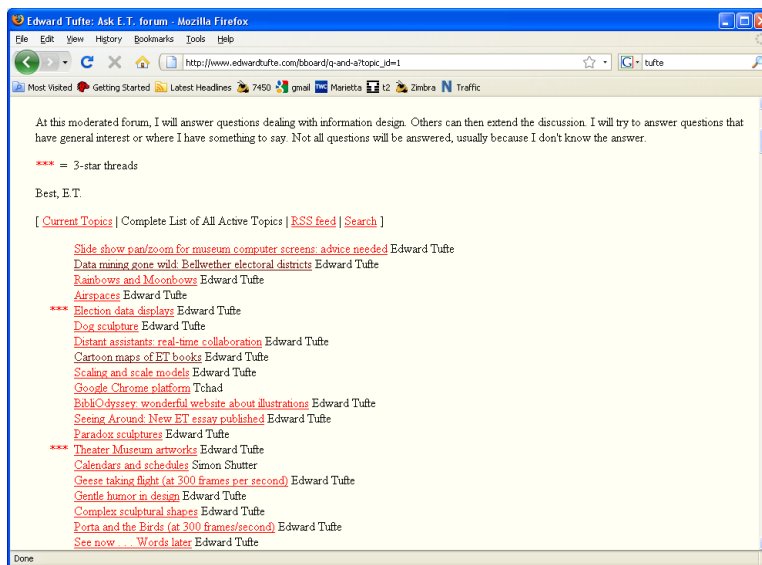
"The Leonardo da Vinci of data" THE NYU VISUAL TIMES

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Discussion Forum



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Interesting Contrast



Nigel Holmes

<http://www.nigelholmes.com>

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More Bad Examples



<http://qz.com/580859/the-most-misleading-charts-of-2015-fixed/>

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Learning Objectives



- Understand and be able to apply Tufte's principles:
 - Graphical integrity (baselines, size coding)
 - Maximize data-ink ratio
 - Avoid chartjunk
 - Macro/micro-readings
 - Small multiples
 - Minimize/unite grids, labeling, legends
 - Appropriate applications of color

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Reading



- Read the quartz.com website just shown

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Upcoming



- Geospatial visualization
- **No class next week**
 - Assignment: Watch a video

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Sources Used



- E. Tufte, *The Visual Display of Quantitative Information*
- E. Tufte, *Envisioning Information*
- E. Tufte, *Visual Explanations*