Design Options

Jörg Cassens

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Universität Hildesheim
medieninformatik
IMAI – Institut für Mathematik und Angewandte Informatik

Inhaltsverzeichnis

Where Are We?

- So far the focus of our attention has been on the uncelebrated but vital preparatory and scoping stages of the data visualization methodology
- We have established the purpose of our design and the key factors surrounding the project have been identified and weighed-up
- We have also acquired and prepared our data and begun exploring it to identify the key data stories and analytical slices around which we may form our editorial focus
- These contextualizing activities are often neglected because they are understandably deemed not as fun as the design stage
- Yet, they will save you time and pain, helping your work to proceed more efficiently by avoiding blind alleys and creative misjudgments

Design Choices

- These contextualizing activities are often neglected because they are understandably deemed not as fun as the design stage
- Yet, they will save you time and pain, helping your work to proceed more efficiently by avoiding blind alleys and creative misjudgments

- In this session, we will be taking a forensic look at the many design choices involved in the process of establishing an effective visualization solution
- We will tackle these choices by working through the anatomy of a visualization design, separating our thoughts into the complementary dimensions of the representation and presentation of data

1 Choices

All About Choice

Jer Thorp
"My working process is riddled with dead-ends, messy errors, and bad decisions—the final product usually sits on top of a mountain of iterations that rarely see the light of day"
☞ blog.blprnt.com/blog/blprnt/138-years-of-popular-science

- We have explored some of the key preparatory activities of the visualization design process
- In doing so we have built a detailed level of clarity about what we want to achieve in our visual communication and why
- The scope for creativity can be quite overwhelming
- How well you rationalize the many decisions you face throughout the process will strongly determine whether you achieve an effective visualization design

Representation

- To frame this discussion, we will do a quick image search in Google for the term "data visualization" and scroll through the first few screens
- You will see just a snapshot of evidence of the innumerable variety of ways in which you can represent data
- Some are good, some are bad
- Some are really bad
- Some shouldn't even be connected with the term data visualization

Creativity

- The first thing to say is that there is never a single path towards a "best" solution
- The inherent creativity and individualism of design work ensures that
- An idealistic desire for a single and simple set of rules to achieve a guaranteed effective solution is simply unreasonable due to the many different factors that will shape the scope and intention of any given project
- There is, however, an established body of theoretical and practical evidence that guides us to understand which techniques work better for certain situations and less well for others

Guidelines

- These guides transcend instinct or personal taste and help us frame many of our design options, influencing the choices we make
- Beyond that it is more about managing trade-offs, about trusting your judgment to make sense of the problem context in which you are working, the requirements you are responding to, and keeping in mind the overall objectives of visualization design

Individuality

- The second key observation is to remark that the very moment we take on a visualization challenge, and start our journey towards a design solution, we are commencing a unique creative route formed by numerous permutations of choices
- Nobody else will go through the same experience nor arrive at exactly the same solution
- As Jer Thorp expressed in his quote, even the best make mistakes and end up wasting time following ideas that lead nowhere and having to change course halfway through
- However, by following the approach outlined here, we hope to reduce the waste and eliminate inefficiency
- This allows us to fail faster and recover more quickly

Reduce Choices

- A useful way to look at a data visualization challenge is to recognize that we are actually seeking to reduce choices
- This is achieved through recognizing influential factors, by considering the desired function and tone of our work, familiarizing with our data and identifying stories
- We are building clarity through selection and rejection
- We are reducing the problem by enhancing our clarity
- The reasoning involved in eliminating options is just as important a skill as determining those we shall pursue
- This lets us control our work, it helps us plan better, and prepare for the creative avenues down which we may proceed

Director

- In many ways you could equate this design process with the responsibilities of being a film director, managing the dramatic, artistic, and technical aspects of a film
- A director has to create the film's vision, direct the cast, manage the crew, oversee the script, coordinate the choice of locations, the music, and the post-production effects
- All these different perspectives require separate attention and unique treatments until they are brought together into a cohesive single product: a movie
- We're trying a similar approach with our visualization design

Representation and Presentation

- Data representation:
  - This is the foremost layer, how we give form to our data through the use of "visual variables" to construct chart or graph types
- Data presentation:
  - This is the delivery format, appearance, and synthesis of the entire design
  - It concerns the layers of color use, interactivity, annotation, and the arrangement of all elements

2 Anatomy – Representation

Representation

- Face-to-face with the demands of achieving that ideal harmony of form and function that was outlined before
- Need to achieve the elegance of a design that aesthetically suits our intent and the functional behavior required to fulfill the effective imparting of information
- Determining how we are going to show what it is we want to say
- Involves considering the following:
  - Choosing the correct visualization "method" for the stories we're telling
  - Accommodating the physical properties of your data
  - Facilitating the desired degree of precision
  - Creating an appropriate metaphor to depict our subject stylistically

2.1 Method

Choosing the Method

- The first matter is to determine the choice of visualization method
- Not necessarily committing just yet to a specific chart or graph type, though we might have some in mind
- Rather, this is about the general family or collection of chart types as defined by their primary storytelling method
- For example, a bar chart serves the function of comparing categories of values
- A line chart, by contrast, enables us to show changes of values over time
- Geo-spatial data can often be best displayed over a map
- Your choice of visualization method will be mostly driven by the your editorial focus and what you have learned about your data

Classifying Methods

- There are a number of ways of classifying the variety of methods for visualizing data, but here is a suggested taxonomy:
  - Comparing categorical values
  - Assessing hierarchies and part-of-a-whole relationships
  - Showing changes over time
  - Mapping geo-spatial data
  - Charting and graphing relationships
- Of course, there are often overlapping functional or storytelling features inherent to the chart types that sit under these method headings

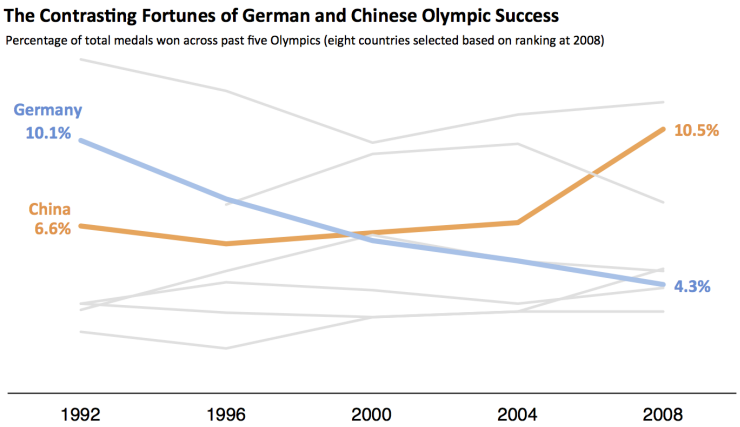
Overlapping Features

- Of course, there are often overlapping functional or storytelling features inherent to the chart types that sit under these method headings
- For instance, a stacked area chart shows changes over time but also facilitates the categorical comparison of its different layers
- That would be an example of a chart type that spans across two method classifications
- However, the principle focus of this chart type is telling a story over time and so we would consider it belonging to the "showing changes over time" method
- The comparisons it enables represent an additional but secondary focus

Example

- As we saw previously, the forming of data questions really helps you articulate the range of analytical stories you are wishing to portray
- In our demonstration exercise, when we were looking to show the results of our analysis, we were essentially responding to the question:
  - "how have the medal-winning performances of China and Germany compared over the past five events?"
- The story being expressed was about showing changes over time: that defines our method
- The selection, ultimately, of a line chart – a type belonging to this category of visualization methods – was evidently a suitable match as we specifically wanted to show the detail of the continuous transition across all five event years

Example Revisited

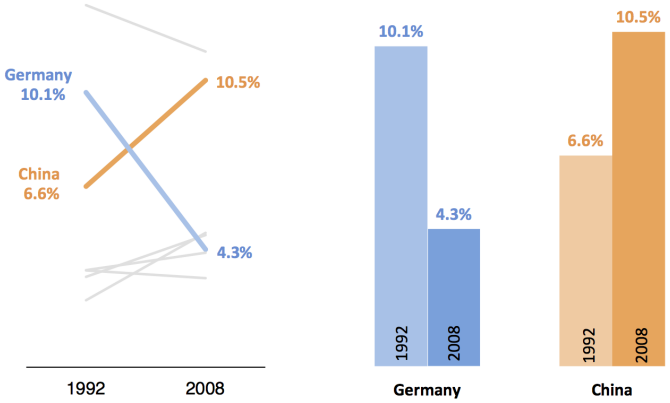


Source: Kirk (2012)

Example: Alternatives

- Had the focus been more about a comparison of all countries and the combined, aggregate picture of results over time we might have chosen a stream graph or an area chart
- Both of these are chart types that would typically fall within the method of "showing changes over time"
- Alternatively, had we sought to demonstrate the stark comparison of the medals won at the earliest and most recent events in our dataset, we might have chosen a method for comparing categorical values
- In this case, the use of a slopegraph or a bar chart would have been more suitable, as shown next

Example: Alternatives



Source: Kirk (2012)

2.2 Properties

Physical Properties

- Learning about the physical properties of your data gives you an important sense of the shape and size of your data
- As you refine your editorial focus you will develop an understanding of the data variables you may seek to display graphically
- The quantity and nature of the variables you are using will have a significant influence on reducing the range of suitable chart types you might be able to use within the method family you have chosen
- As discussed earlier, this process of eliminating choices can only be of help to us as we move forward

Example

- Referring back, once again, to our demonstration for the Olympics project, the data we were looking to use for our final story was
  - event year (quantitative interval-scale)
  - medal totals (quantitative ratio-scale)
  - country (categorical nominal)
- We had a good sense of the range and distribution of values held against each variable, we were just highlighting two countries and we wanted to show the full five-event transition
- The best solution, therefore, was to use the line chart as we have just seen
- We will go into much more detail about this taxonomy and the range of chart types that sit underneath each of the five headings

2.3 Precision

Precision

- Precision is a minefield.
- Having identified the general visualization method and started to filter down further to identify the most suitable chart types, we now have to consider another key issue
- This judgment gets to the very heart of the form/function or art/science fault lines that exist in this field—to what degree of accuracy do you wish readers to be able interpret values from your visualization
- Why would you ever not wish to maximize the precision of interpretation?
- Surely, the mission is to deliver as much accuracy through our representation as possible?

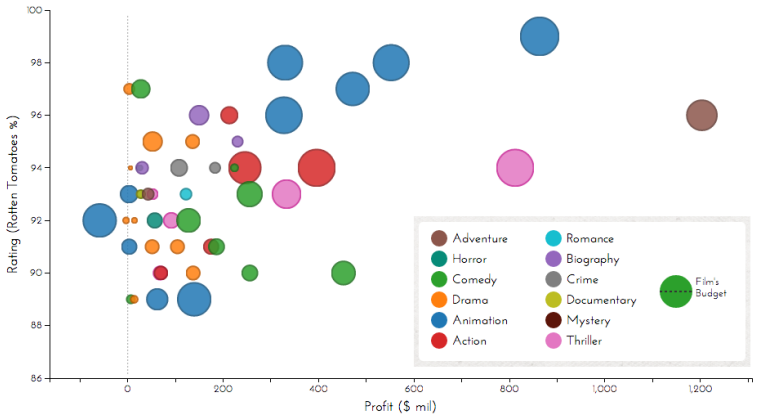
Visual Variables

- Of course we do, but the inclusion of terms such as “maximize” and “as possible” allude to the specter of alternative influences
- For certain contexts, as we outlined previously, you might be seeking to explore different aesthetic forms of representation
- Sometimes this might involve certain sacrifices in terms of the precision of interpretation
- To frame this, we first need to learn about visual variables
- A visual variable is the specific form we assign to data in order to represent it visually
- It could be the length or height of a bar, the position of a point on an axis, the color of a county on a map, or the connection between two nodes in a network

Multiple Variables

- Each of the chart types that we come to take as common representation methods are based on the deployment of a single or, more commonly, combination of several visual variables at once
- Using multiple variables, in particular, enables a designer to efficiently express extra layers of meaning behind the properties of a single mark, as the next example demonstrates

Visual Variables: Example



Source: Kirk (2012)

Example

- In this bubble chart visualization, each mark involves a combination of several visual variables representing a range of different data variables:
  - The position on the x axis represents a film's profit
  - The position on the y axis represents the average review percentage rating of each film
  - The circle area represents the film's budget
  - The circle's color (hue) represents movie genre
  - Users interacting with this web-based design will also discover a text label displaying the raw values by hovering over one of the bubbles
    - Text is not universally treated as a visual variable but it is still worth acknowledging
- If you let your imagination run free and try to conceive as many visible properties as possible that might be capable of representing series of categorical, ordinal, or quantitative data, you will realize that there are many potential approaches

Jacques Bertin

- Jacques Bertin was a pioneering thought-leader within data visualization
- Building on the earlier studies from the Gestalt School of Psychology, his book Semiologie Graphique (1967) is one of the subject's founding texts and represents one of the earliest and most comprehensive attempts to theorize how we perceive and interpret different representations of data through shape, pattern, and color
- Bertin determined that there were three main aims behind your choice of data representation, moving from high-to low-level acts of graphical interpretation
- This is still an extremely potent way of organizing our thoughts and reasoning our selection of the most effective visual variables

Bertin's Hierarchy: Discriminate

- The highest level of Bertin's interpretive acts concerned whether we are able to visually discriminate between different data marks or data series
- can we actually see and read the data being presented?
- We must make sure that the way we visually distinguish different categorical and quantitative values is legible and is in no way hidden by way of unnecessary clutter, noise, or distraction

Bertin's Hierarchy: Order or Ranking

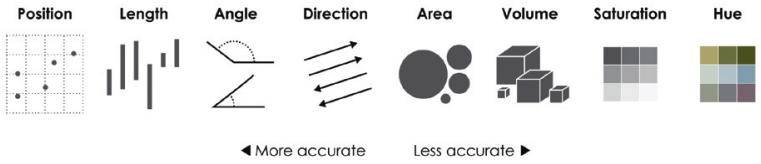
- The second act refers to being able to satisfactorily judge the relative order or ranking of values in terms of their magnitude
- This is basic pattern matching where we seek to determine the general hierarchy of the values being displayed
- where is the most and where is the least, which is the biggest and which is the smallest

Bertin's Hierarchy: Values

- The lowest-level act relates to judging values
- Studies have shown how the effectiveness of different visual variables can be ranked based on which most accurately support comparison and pattern perception

Cleveland and McGill

- Bertin was the first to propose such a hierarchy and his work has been tested, developed, and refined by Cleveland and McGill
- The focus of the study was to determine how accurately people read the visual cues above (excluding shapes), which resulted in a ranked list from most accurate to least accurate

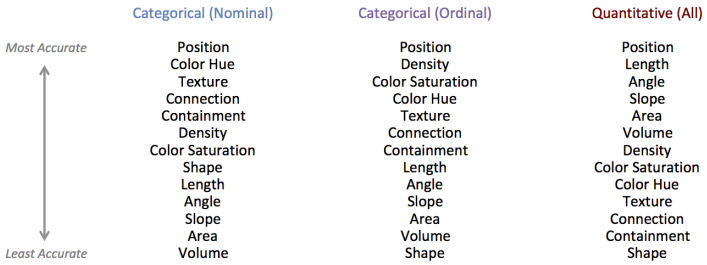


Source: Yau (2013)

Jock MacKinlay

- In the following presentation, we see the most recent version created by MacKinlay
- Each column represents the three main data types
- note that there is no distinction between ratio and interval-scale types of quantitative variables
- Within each column you have an ordering of the most accurate and least accurate visual variables according to their interpretive precision

MacKinlay: Ranking



Source: Kirk (2012)

Rankings

- The studies by Bertin, Cleveland and McGill, and then MacKinlay focus on the fact that our visual system isn't capable of absolute measurements
- Therefore, frameworks like this simply propose a guide to understand which variables will be better at delivering relative measurements but with highest accuracy
- In other words, the higher up the column the easier it will be for your reader to accurately interpret values represented by those variables
- So, looking at that table, you might ask why you would ever not use position as the visual variable for your data
- That will surely maximize the efficiency and accuracy of your data communication for all data types?

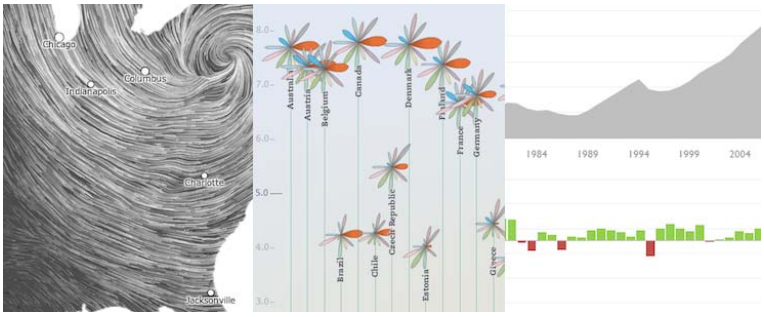
Multiple Variables

- Unfortunately not as simple as that
- As we've seen earlier, we rarely only have just one data variable to communicate
- You will therefore often need multiple visual variables to communicate multiple data variables
- However, above that, and returning to our section introduction, how accurate do we really need the interpretations to be?
- Do we actually need to facilitate the reading of exact values from every visualization we create?
- Alternatively, can we allow ourselves more creative freedom by recognizing that in some cases just being able to facilitate the relative order of values may be sufficient for the context and requirements of the design?

Visual Quality

- We discussed the importance of trying to define the functional and tonal quality of your intended design
- The tonal judgment, in particular, is the important matter right now for this is what separated those pieces that matched an analytical and pragmatic style from those that were more abstract or emotive
- In the next image we see a selection of visualization styles and demonstration of the fine balance being judged between design creativity and interpretive accuracy based on the contextual requirements
- We will take a closer look at each one at a time

Example

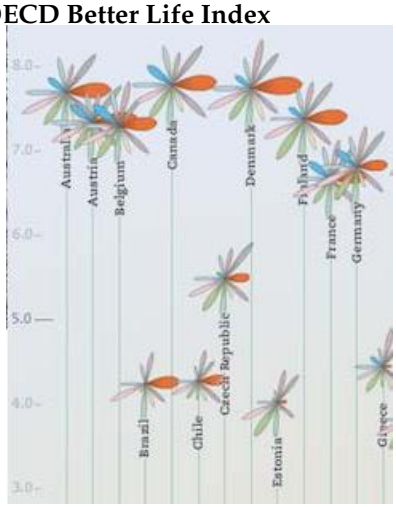


Source: Kirk (2012)

Wind Map

- Doesn't aim to facilitate the reading of exact values
- The use of pattern density to indicate the strength of the wind, as shown in the hierarchy table, focuses on delivering a sense of those areas with strong wind (as well as its direction) and the areas where there is little wind
- The elegance of the resulting design makes for a compelling visual that draws users to interact and learn about the patterns

OECD Better Life Index



- Not easy to determine precise values from these shapes but we do get a sense of the big values, the medium values, and the small values
- Attractive alternative to a very pragmatic and analytical display such as a bar chart
- At this primary layer of the tool's interface, the balance achieved between design creativity and interpretive accuracy was judged to be ideal, with the added feature of interactivity to enable more detailed annotation and accurate value-reading

Area and Bar Chart

- The example of an area chart and bar chart provides a contrasting context
- Here we might be talking about an analytical experience where the accuracy and efficiency of exchange is paramount
- The idea of design innovation or novel creativity is not important
- In these cases, you will be looking to prioritize the deployment of the higher-ranking visual variables enabling a reasonably easier experience in reading the values

2.4 Metaphor

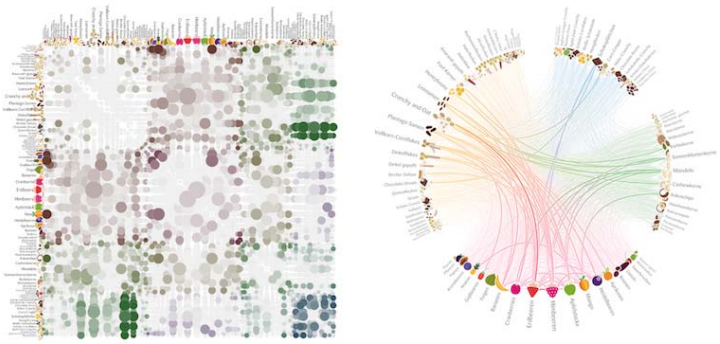
Metaphor

- Visual metaphors are about integrating a certain visual quality in your work that somehow conveys that extra bit of connection between the data, the design, and the topic
- It goes beyond just the choice of visual variable, though this will have a strong influence
- Deploying the best visual metaphor is something that really requires a strong design instinct and a certain amount of experience.

Metaphor: Example

- In this next example, designer Moritz Stefaner was commissioned to analyze and visualize how the clients and customers of a German start-up muesli company combined the ingredients they offer
- The end result was a static visualization based on a radial network or chord diagram, showing ingredients grouped by category (base mueslis, fruit, nuts, sweets, and so on)
- When describing his design process, Moritz noted how, when he worked on different sketches of the data, the matrix chartrevealed some particularly strong stories that were otherwise missed in the radial diagram
- So why was the radial diagram picked?
- He commented: "from a visual point of view, it does not look very tasty."
- The radial diagram looked more appetizing, The matrix chart solution looked more like fungi

Example: Muesli



Source: Kirk (2012)

3 Anatomy – Presentation

Presentation

- The presentation of data involves thinking about pretty much every other design feature that might be included in our visualization
- Here, we are determining the following:
  - The use of color
  - The potential of interactive features
  - The explanatory annotation
  - The architecture and arrangement
- The decisions we make about these layers should be focused on delivering extra meaning, intuitiveness, and depth of insight to our readers or users

Invisibility

- One of the key concepts throughout our judgment of presentation-related design options is to seek to make the visible, invisible
- In contrast to data representation, where our objective is to make the invisible stories and insights, visible, data presentation features should almost feel invisible so that the portrayal of the data maintains visual dominance
- Therefore, try to bear the following two things in mind:
  - Visual inference means data inference
  - Facilitating the resemblance of data

Visual Inference

- Visual inference means data inference: If it looks like data, it should be data
- If it isn't data then you've incorrectly conveyed a sense of representation where there isn't any and design refinement is required
- An example might be the use of a color to represent a certain sentiment
- If that color is used on a bar chart or is picked for the background of a label or call-out, but it is no longer connected to the representation of any sentiment meaning, this may trick the reader who has programmed their visual sense to spot this inference

Resemblance of Data

- Facilitating the resemblance of data: Let the data breathe
- We talked about this in the discussion about Jacques Bertin's interpretative acts, but the presentation layers of your visualization will have a great impact on this
- Ensuring a reader can discriminate between data categories and values is usually influenced by the background artifacts and surrounding apparatus
- Throughout your design, make sure your data stands out clearly as the principle visual component

3.1 Color

Color

- We've already touched on various aspects of using color as a potentially important visual variable for the representation of data, but the deployment of color for a visualization project naturally extends further
- Given the depth and breadth of the field of color theory, it is important to consider it separately from our other design choices
- When deployed poorly, the use of color can create unnecessary decoration that can distract and compete undeservedly for attention in ways that will undermine the clarity and accessibility of the information exchange
- Conversely, with effective use of color we can deliver an attractive, synthesized design that most efficiently taps into the preattentive nature of the eye and the brain

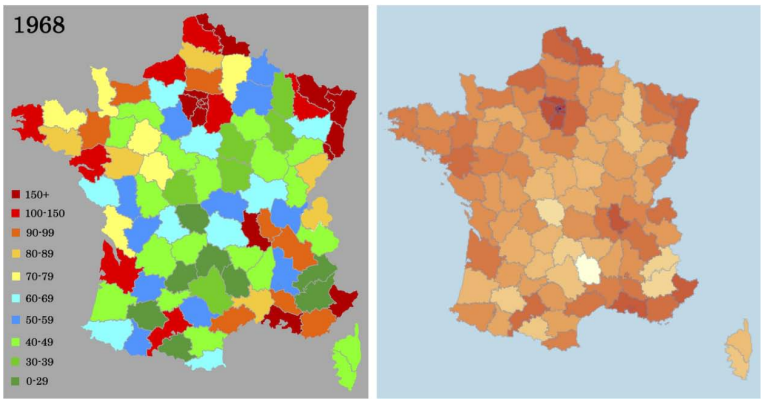
Use of Color

- We are seeking to create layers of visual prominence that help us instantly achieve a sense of the important messages and features
- Take a look at a landscape painting and witness the depth that is created through color, the separation between foreground and background that helps elevate prominent features and relegate contextual properties
- Make sure color is used unobtrusively and it does not mislead by implying representation when it shouldn't be
- Important to be aware of the different functions, choices, and potential issues surrounding color deployment

- To represent data One of most common mistakes used in relation to color is seen when it is being deployed to represent quantitative data
- Specifically, when the "hue" property of color is used
- Take a look at this spectrum of colors: if these squares were representing quantitative data, which would be the biggest? How about the smallest?
- Which is bigger, red or blue?

Source: Kirk (2012)

Example: Hue or Saturation



Source: Kirk (2012)

Example

- In the previous pair of images, on the left-hand side, even with a color legend explaining the value bands being depicted by the different colors, there is no preattentive association that allows us to efficiently determine the values being represented on the map
- Referring back to Bertin's interpretive acts, we can't even easily establish a general sense of big, medium, and small values without having to constantly move to-and-fro the map and the legend
- By contrast, the map on the right-hand side uses a single hue and uses a sequential color scheme that represents the highest values (dark) to lowest values (light) in a logical and immediately understandable way

Sequential Color Scheme

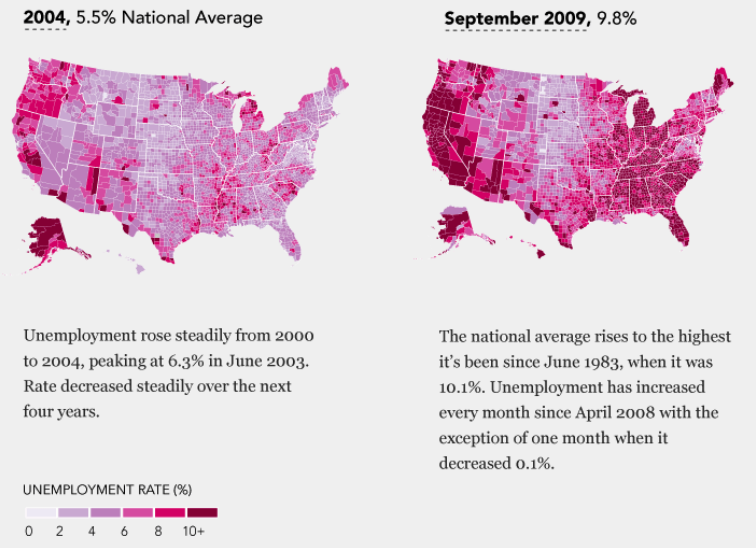
- What we can see demonstrated in this example is that, for quantitative data, one of the best ways to effectively depict a range of quantitative values is through the saturation (lightness) property of color: that is, a scheme which goes from the most intense color through to increasing amounts of white
- This is sometimes called a sequential color scheme

Source: Kirk (2012)

Sense of Order

- As we can see clearly in this next display, we inherently and automatically attach a sense of order to such sequential scales
- Of course, without a key it might be difficult for us to precisely pick out the absolute values that each color band represents, but we can certainly determine major patterns that lead to judgments of data order within and across both sample maps
- That idea, of surfacing the general patterns of the highest and lowest values, is really what the main purpose of color is when used to represent quantitative variables

Example



Source: Yau (2013)

Sequential Color Scheme (contd.)

- A sequential color scale is used to represent a single variable without a separation requirement (positive versus negative, for example)
- Darker shades typically represent higher values and lighter shades represent lower values
- You essentially choose a saturated hue and then decrease the saturation in increments to create a scale
- With the sequential scales in the following example, the saturated hues are on the right and saturation is decreased as you shift left

Overview Color Schemes

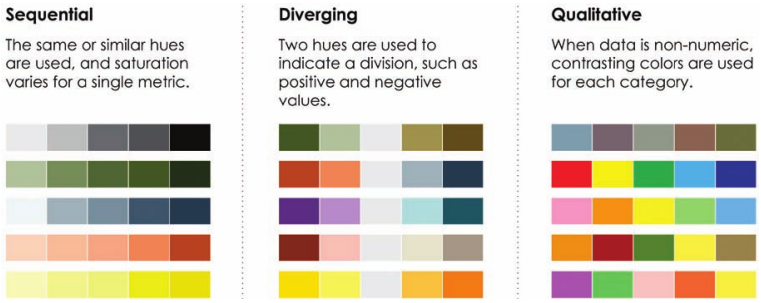
Source: Yau (2013)

Diverging Schemes

- When you do have a natural or defined split in the data, such as increases and decreases or political leanings toward two parties, you can use a diverging color scale
- It's like a combination of two (or more) sequential color scales with a separator in between to indicate a neutral value, such as a change of zero or a balance of political favor
- While there is a variety of different ways to construct diverging color schemes, typically, the extreme ends of the spectrum are presented as darker and distinguished by strongly contrasting color hues
- Alternative approaches might involve exploiting established color metaphors or might already be intuitively understood or easily learned

Qualitative Scheme

- Qualitative color scales are useful when your data is categorical or non-numeric
- Each color might represent a category, and the varying shades should provide visual separation



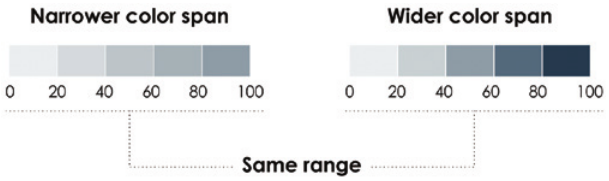
Source: Yau (2013)

Variation

- Regardless of the type of color scale you use, there should be enough variation between your choice of hues and saturation so that you can see differences
- Choose shades that are too similar and it's a challenge to make comparisons
- A narrow color span restricts the amount of difference between shades
- A wider color spanmakes it easier to see differences
- This works in the opposite direction, too
- A color span that's too you don't pay attention to the context of the data, you might show patterns that look obvious but are not significant

Variation (contd.)

- This works in the opposite direction, too
- A color span that's too wide can exaggerate differences
- If you don't pay attention to the context of the data, you might show patterns that look obvious but are not significant

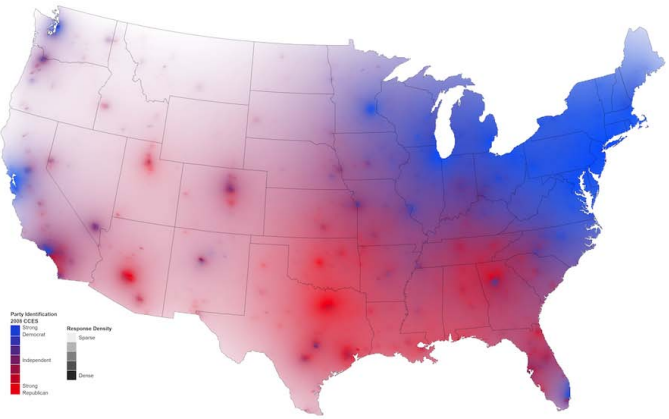


Source: Yau (2013)

Utilizing Color Understanding

- The next image is an example of where preprogrammed understanding of color representation can be utilized. In this case, we see the respective strength of party political support across the U.S., with the Republicans represented by their established red and Democrats in blue
  - Cultural representation
- This is a topological map that displays calculated contours to show the general spread of support for each party
- An added dimension to this particular piece is the use of an extra representation – color transparency – to represent population density, thus adjusting the display to accommodate the lack of population uniformity

Political Persuasion Map

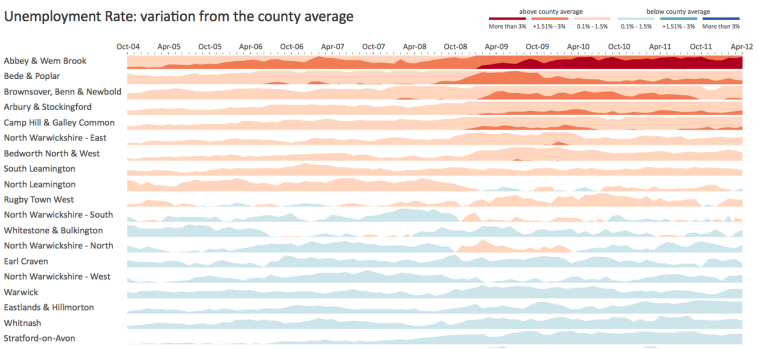


Source: Kirk (2012)

Traffic Light Metaphor

- It isn't just on maps where properties of color can be important to distinguish quantitative values
- One of the most popular methods for coloring involves the traffic light metaphor of red, yellow, and green
- This is commonly used in corporate settings to indicate good, average, or bad performance thresholds
- However, keep in mind that around 10 percent of the population (particularly males) has a red-green color deficiency
- The use of an approach such as the traffic light colors will therefore potentially alienate a significant proportion of your intended audience
- An effective alternative is to switch green for blue, so positive values are now shown as blue and negative are still in red, as we see in the following horizon chart

Modified Traffic Light Metaphor

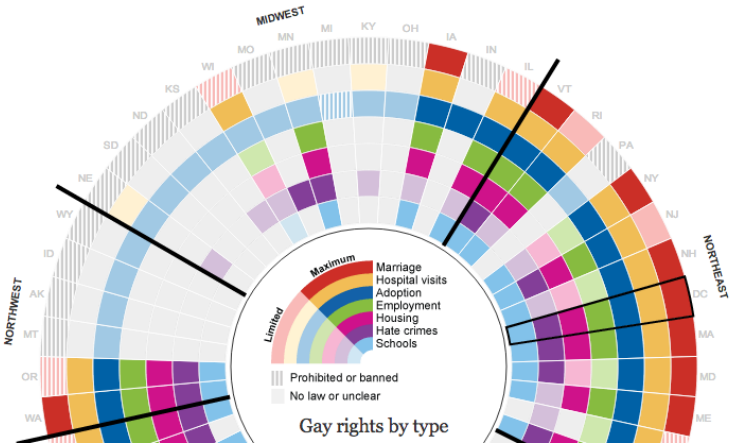


Source: Kirk (2012)

Example Qualitative Scheme

- In the next example, we see a project created to display the status of various indicators surrounding how different states around the U.S. handle gay rights issues
- There are seven distinct categories of data distinguished by a unique color
- The color itself has no meaning; it is purely a means of helping to separate out the various tracks of issues
- The lightness of the color does add an extra layer of information, indicating where maximum (darker) and limited (lighter) rights are in place, and the absence of any color as well as the presence of a cross-hatching pattern further encodes extra meaning

Example Gay Rights



Source: Kirk (2012)

Example Discussion

- As we saw in the earlier image showing the political persuasion map of the U.S., the use of color for categorical data also allows us to maximize the implication of metaphorical or representative association
- However, regardless of whether the color depiction of categories is arbitrary or embodies more meaningful association, one of the key rules we need to obey is that the eye is only really capable of distinguishing up to a maximum of twelve different color classifications
- I addition, the shape of the visualization evokes the rainbow flag symbol of the LGBT rights movement

Rainbow Flag

Source: ☞ Ludovic Bertron

Many Categories

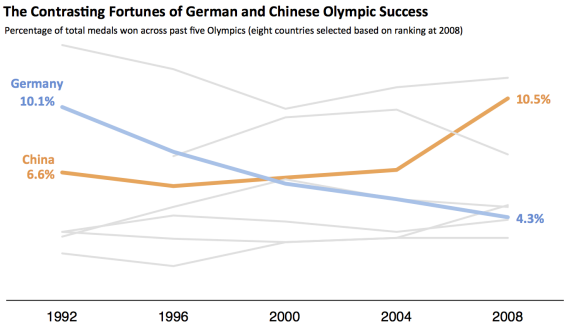
- If you have more than twelve categories you may need to find ways of combining classifications to avoid this issue
- You'll see this in effect on images such as the many subway maps around the cities of the world
- As more extended lines and routes emerge, there are fewer remaining distinct color options that will help to emphasize, indicate, and separate these new markings
- There are also many definitions about the emotional or cultural significances behind color representation
- It is naturally advantageous to exploit universal visual languages, but only when they are definitely universal
- You need to be sensitive to the potential differing perceptions of color meaning across the regions of world

Foregrounding

- To bring the data layer to the fore
- In addition to the representation of data, we also look to employ color to help create visual depth and a sense of hierarchy in our designs
- The clutter that can occur between background presentation and the foreground data representation makes it a real challenge to efficiently establish a sense of visual hierarchy
- The brain and the eyes otherwise have to work especially hard to draw any insight
- What we are trying to establish is a clear sense of the most important signals brought to the foreground and the less important contextual or decorative elements pushed into the background

Foregrounding (contd.)

- We saw this effect successfully demonstrated by our proposed solution for the Olympics demonstration in the previous chapter
- Here, the main focus surrounding the narrative of China and Germany's transition over time was achieved by promoting their series of values strongly into the foreground through color

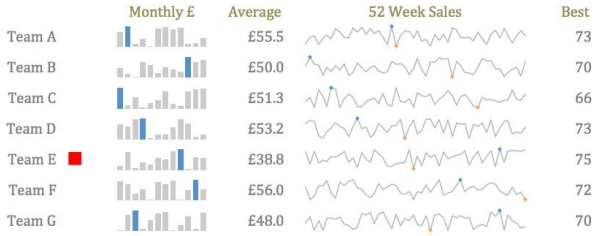


Source: Kirk (2012)

- The rest of the value series for the remaining countries, as well as the chart apparatus, were relegated subtly into background but were still visible and available for reference

Foregrounding Example

- We see a similar effect demonstrated by this following image taken from a typical dashboard display
- By their very nature, dashboards are deployed in situations whereby the efficiency and accuracy of detecting key message as signals is a key aim



Source: Kirk (2012)

Hierarchies

- In this example, we see a limited, rather monochromatic color scheme applied across all properties – values, charts, labels, and titles
- Through deploying this soft palette, it enables the key signals to jump in to the foreground as the most important visuals:
  - the red indicators (alerting a need for further investigation)
  - the blue headline bars (best performance)
  - the very subtle markers on the sparklines to represent the highest (blue) and lowest (orange) weekly levels
- When it comes to learning about the potential of color to create a sense of hierarchy, we can take inspiration from the effective deployment of color witnessed in other contexts

What Colors?

- When it comes to judging background colors, there is no definitive set of rules about whether light (typically white) or dark (typically black) colors are better or worse
- It is always a contextual judgment based on the intended style of the project as well as the palette of colors from which you intend to represent data
- It is essentially a judgment about the legibility of contrast between foreground and background chart properties
- As a general piece of advice, try not to use strong, highly saturated colors when covering large areas. Don't force the eye to have to constantly contend with and process dominant colors
- Instead, give yourself the option of using strong colors to highlight and draw attention to the data layer

Dampening

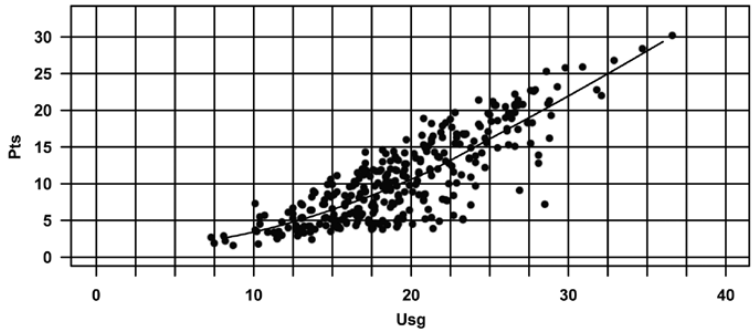
- Another important property to take notice of, in the relationship between foreground and background, is the careful deployment of chart apparatus, such as the axes, gridlines, tick marks, borders, titles – any chart property you may use to frame and reference your data
- Don't be afraid to remove or dampen the visible presence of such elements, particularly as the defaults in many tools are set to black
- We are automatically tempted to make things darker, bolder, more prominent, more imprisoned
- Where possible, minimize, dampen, or even remove some of these chart properties because we want to let the data stand out and facilitate our "seeing" of its qualities

Visual Hierarchy

- When you look at visualization for the first time, your eyes dart around trying to find a point of interest
- When you look at anything, you tend to spot things that stand out, such as bright colors, shapes that are bigger than the rest, or people who are on the long tail of the height curve
- You can use this to your advantage as you visualize data

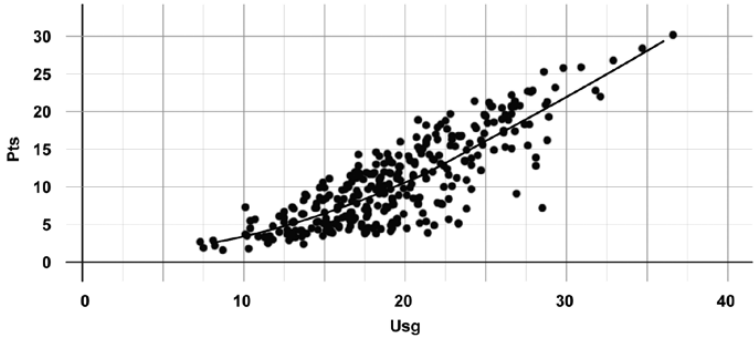
- Highlight data with bolder colors than the other visual elements, and lighten or soften other elements so they sit in the background
- Use arrows and lines to direct eyes to the point of interest
- This creates a visual hierarchy

Scatterplot: First Try



Source: Yau (2013)

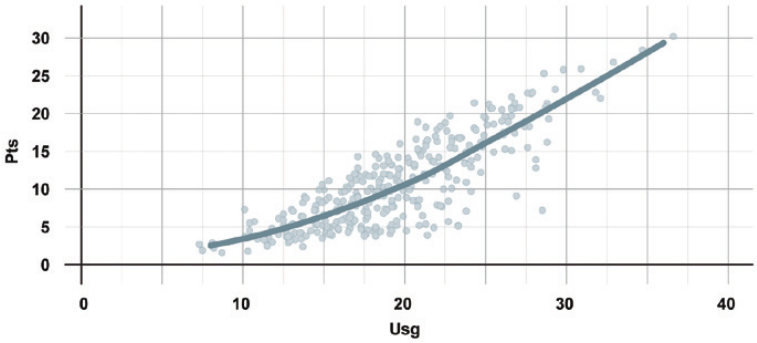
Scatterplot: Grid



- The line width of the grid lines is reduced so that they are no longer as thick as the fitted line
- They also alternate in width so that it is easier to see where each data point lies in the coordinate system

Source: Yau (2013)

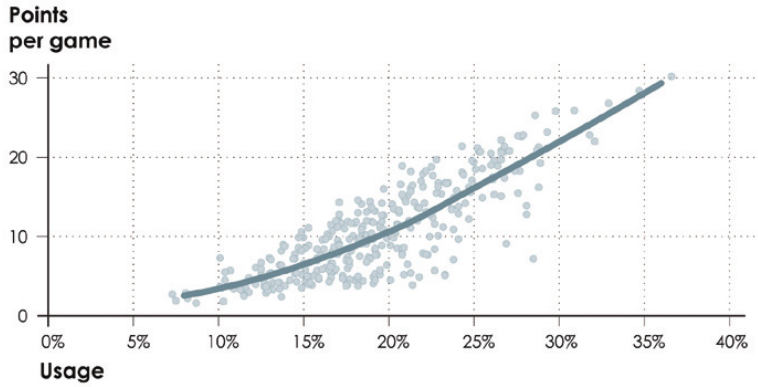
Scatterplot: Use of Color



- We change the color to blue to make the data stand out more, and the width of the fitted line is increased so that it clearly rests on top of the dots

Source: Yau (2013)

Scatterplot: Use of Labels



- more descriptive axis labels and less prominent value labels can help

Source: Yau (2013)

Other Elements

- This extends to elements like titles
- The following are two contrasting title designs for a visualization project that was undertaken about the history of Olympic speed.

Source: Kirk (2012)

3.2 Readability

Readability

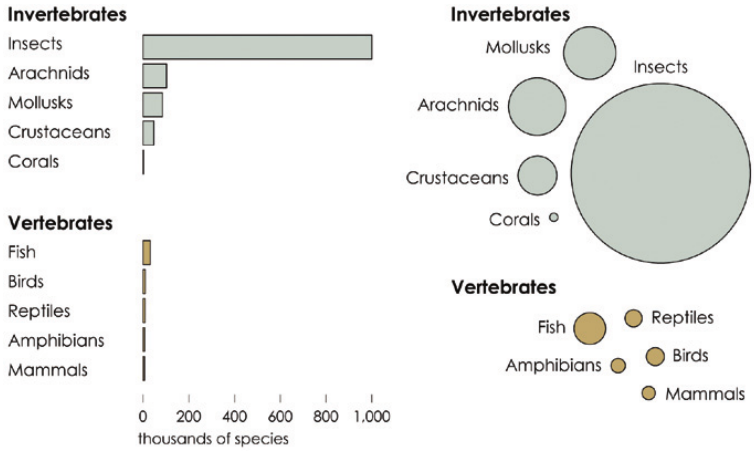
- An author who uses words to describe a world or character interactions makes abstractions so that a reader can picture what's going on
- Poor descriptions and little character development challenge readers to make sense of what seem like obscure clues
- If readers can't connect the dots and understand what the author tries to describe, the words lose their value
- Similarly, you encode data with visual cues when you visualize it, and then you or others have to decode the shapes and colors to draw insights or to understand what a visualization represents
- You must instead maintain the connection between visual cues and data because the data is what connects a graphic to the real world. So readability is key

Allow Comparisons

- Allowing comparisons across points is the main purpose of visualizing data
- In table form, you can compare only point by point, so you place data in a visual context to see how big one value is relative to the rest and how all the individual data points relate to each other
- As a way to better understand data, your visualization isn't useful if it doesn't fill this basic requirement
- Even if you just want to show that values are equal across the board, the key is still to allow that comparison and conclusion to be made

Comparisons: Example

- For example, the next Figure shows a number of identified species of invertebrates and vertebrates
- The bar chart on the left and the bubble chart on the right show the same data, but because there so many more identified species of insects than vertebrates, the bars for the latter are dwarfed
- They are barely visible, and the bar for corals is also just a sliver
- On the other hand, the bubbles let you put large and small counts in the same space
- The downside is that you can't visually compare values as accurately as a bar chart, but in this case, the bar chart doesn't even give you a chance to compare the values
- So there's a trade-off



Source: Yau (2013)

Represent Context

- Context helps readers relate to and understand the data in a visualization better
- It provides a sense of scale and strengthens the connection between abstract geometry and colors to the real world
- You can introduce context through words that surround a chart, such as in a report or story, but you can also incorporate context into the visualizations through your choice of visual cue and design elements

Context: Crayola

Source: Yau (2013)

Context: Crayola

- Stephen Von Worley showed the increased variety of colors in the Crayola crayon spectrum
- In 1903, on the release of the first wax crayons under the brand name Crayola, there were just 8 colors
- Over the years, Crayola inherited and created other colors in between the existing hues, and by 2010, there were 120 shades offered.
- In addition to red, there is now also bittersweet, brick red, mahogany, maroon, orange red, red orange, violet red, wild watermelon, radical red, razzmatazz, fuzzy wuzzy, and scarlet.

Context: Movies

Source: Yau (2013)

Context: Movies

- The charts in the last Figure show movie trilogy ratings from the review aggregation site Rotten Tomatoes
- On the site, a ripe red tomato is used for movies that earn at least 60 percent positive reviews (fresh), whereas a splattered green tomato is used for movies below the 60 percent threshold (rotten)
- The graphs match the site's color scheme so that you can easily see which movies were fresh and which were rotten
- The length of each bar provides a more exact value.

Highlighting

- Highlighting can guide readers through the data and direct eyeballs to the most important parts in a graphic
- It reinforces what people might already see or draw attention to areas or data points that people should see
- To draw visual attention to a data point, you simply do what you would in real life
- You make it stand out. Speak a little louder. Make it a little brighter.
- Edit an area or point in a visualization – while keeping the data, its visual cues, and readability in mind—to differentiate it from the rest
- Use a brighter or bolder color, draw a border, thicken a line, or introduce elements that make the point of interest look different

Highlighting: Color

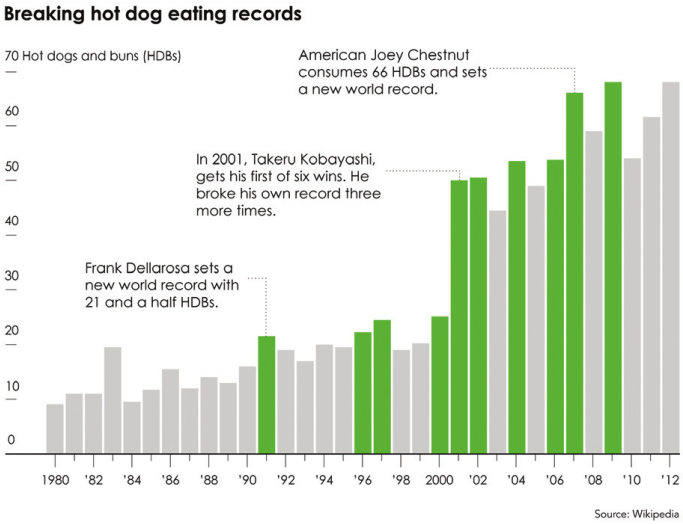
Source: Yau (2013)

- This Figure shows how to use color to highlight a specific point
- Most of the shapes are a neutral color, and the point of interest is purple, so attention immediately focuses on the parts that stand out

Focus in Time Series

- Visualize time series data, and you might focus on specific years, such as seen next
- As you know, America loves their competitive eating, and no contest is more important than the annual hot dog eating contest on Coney Island
- The top bar chart shows the number of hot dogs and buns that winners ate each year, but you can highlight bars to shift focus to years when someone broke a world record or when a certain person won

Example: Hot Dogs

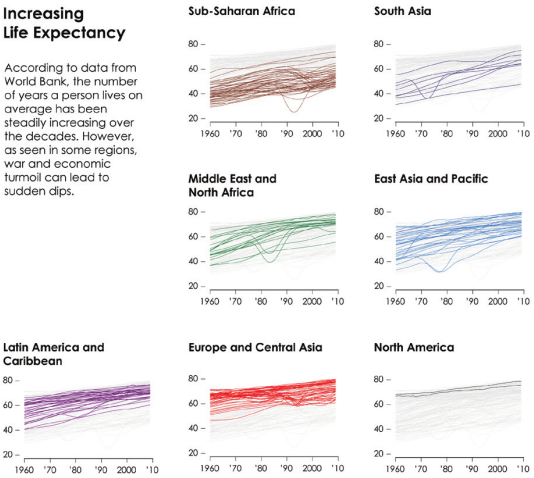


Source: Yau (2013)

Focus in Time Series (contd.)

- On to more important matters: the next Figure shows the world life expectancy chart categorized by geographic regions
- Each line represents a country's time series
- The graphic shows all the countries that data was available for but shifts focus for each region
- So the current point of interest is highlighted and brought to the front, and the rest are moved to the back and made a light gray, which remain for a sense of scale and context

Example: Life Expectancy

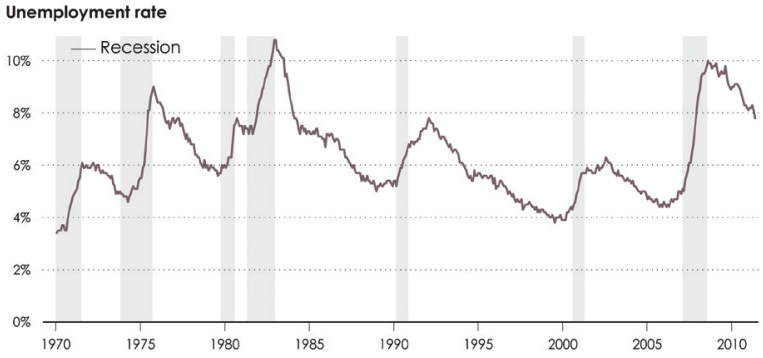


Source: Yau (2013)

Background Highlighting

- Highlighting doesn't always have to be front and center
- You can put it in the background, as shown next
- The unemployment time series data still keeps focus, but gray bars highlight periods of recession and provide information outside the primary dataset

Example: Background Highlighting

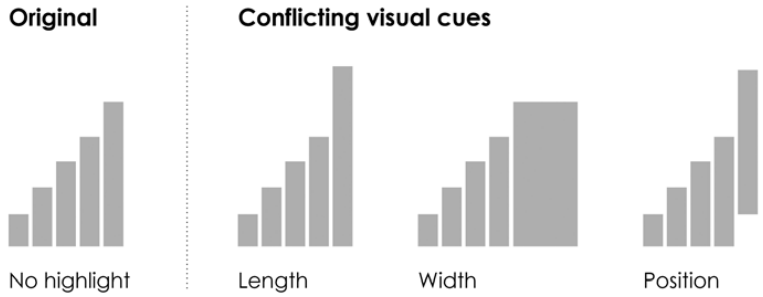


Source: Yau (2013)

Highlighting: Conflict

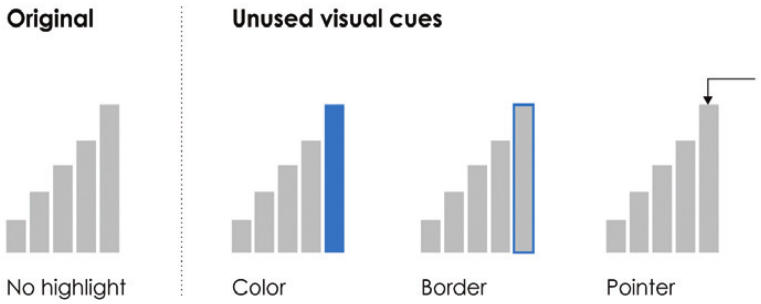
- However, wherever your highlighting fits in the hierarchy, be sure the new visual cues don't conflict with existing ones
- If you have a bar chart that uses length as a visual cue, you obviously do not highlight with length, too
- Have a scatter plot? Don't highlight with position
- Heat map? Highlight with the color palette rather than introduce hues that change visual patterns

Don't



Source: Yau (2013)

Do



Source: Yau (2013)

3.3 Interactivity

Interactivity

- The very best examples of interactivity manage to make the visible, invisible
- That is, the functions of interactivity blend into the design so seamlessly and intuitively that the apparatus of interaction is inseparable from the data portrayal – we no longer view it as a tool wrapped around a data visualization
- Inevitably, the potential development of an interactive design requires technical capabilities
- Referring back to your early thoughts about the purpose of your project, you also need to carefully consider the motivation and intention of this design
- Specifically, what functional experience are you trying to create for your audience: is it an exploratory, explanatory, or maybe a combined design?

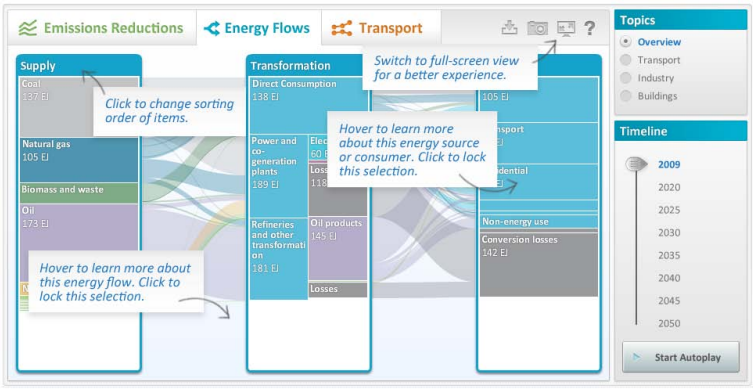
Useful?

- Remember, just because you can create interactivity doesn't always mean it enhances the user experience of engaging with data visualization
- Don't compromise the essence of your visual communication by abandoning a static design just for the novelty of creating interactivity
- Conversely, if the complexity and variety of the data structures that you are working with make it incompatible with a static portrayal, that's exactly the situation that warrants interactive features

Example Interactivity

- The following interactive Sankey diagram is a perfect demonstration of a project that effectively integrates a host of useful interactive features that maximize the exploratory potential of the subject matter
- It was developed to present a breakdown of the flow of different sources and types of fuels, from supply through transformation, and to end usage
- Notice, through the annotated tips, the range of different actions you can trigger in order to see the data from many different perspectives
- That is a key factor behind the deployment of interactivity – being able to take on multiple views of a subject matter to really understand the stories emerging

Example Interactivity



Source: Kirk (2012)

Variables and Parameters

- Manipulating variables and parameters
- The complexity of some data frameworks often means we are trying to find ways of showing many dimensions of stories within a single display or to facilitate different combinations of variables for exploratory visual analysis
- The ability to select, filter, exclude, or modify certain variables is a valuable way of letting the user interact with different slices of the data
- Furthermore, grouping and sorting options are common facilities for extracting new insights

Variables and Parameters (contd,)

- In the Sankey diagram example, you can isolate any of the vertical segments to see the breakdown and flow of those individual components across the entire system
- You can also modify the variable of time using the slider to see changes across numerous yearly milestones
- A technique called "brushing" – highlighting a set of data marks – is another powerful way of focusing in on a subset view of our presented data, particularly with scatter plot type displays

View

- Adjusting the view
- In contrast to manipulating variables, this is more about adjusting the user's lens or window into the subject
- When we have hierarchical or high-resolution data, the ability to perform vertical exploration through the different layers of detail is an important feature
- This can be particularly valuable in map-based visualizations where you may wish to pan around the landscape and zoom through different levels of magnification
- You would see the benefit of this in a project such as the "Wind Map" that we saw earlier, enabling the user to dive into different parts of the country or those areas with strong winds that would be interesting to see in more detail

View (contd.)

- An additional element of view adjustment is to create different horizontal tabs or panels of data. For example, if you wanted to show your data stories via a series of explanatory sequences
- Collapsible devices such as concertinas allow for extra detail to be neatly organized hidden away from the default view and revealed when required
- In the energy flow example, we also see a full-screen option that enables users to optimize the screen space occupied by the interactive

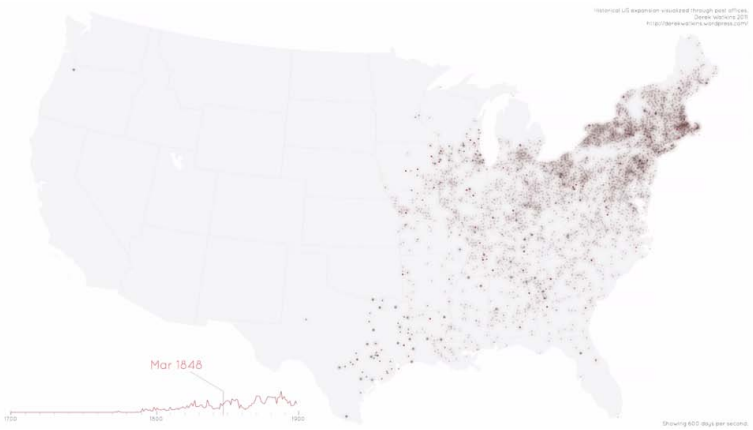
Annotation

- Annotated details
- in interactive terms, this is about creating extra layers of data detail through interactive events such as hovering or clicking
- This is particularly useful if you want to reveal actual data values or extra detail about a given category or event
- In the earlier section we discussed the degree of accuracy in interpretation and we saw an example of an interactive bubble chart
- As you hovered over the bubbles, you saw a pop-up text display with the raw numbers
- The availability of this type of detail, just a click or hover away from view, might give us greater creative license

Animation

- When we have time-series based data, there is great potential for us to portray our visualization through animation, creating a shifting scene of data as it unravels a compelling data story
- The use of features such as Play, Pause, and Reset can be enhanced by offering manually controllable time sliders (seen in the earlier energy flow example) as well as chapter navigation to skip through key milestones
- The following example below, depicting the expansion of post offices across the U.S. through the years 1700 to 1900 is a perfect demonstration of the potential power of animated data presentation
- While the individual frames are interesting in their own right, the real power of this portrayal comes through the emerging story of the social history of population growth and migration across the country

US Postal Offices



Source: Kirk (2012), ☞ blog.dwtkns.com/2011/posted

Animation (contd.)

- One thing to bear in mind is that our memory capability is ill-equipped for remembering the previous scenes of an animated story
- If the facilitation of comparison is important, then animation may not be the best method and something like a panel of small multiples will be more effective
- The deployment of features such as trailing certain categories or the amplification of new values as they change significantly over time can also help compensate for this shortcoming

3.4 Annotation

Annotation

- Our next layer is one that can often be neglected
- However, annotating visualization is an important features of our design
- It is about taking care of your audience, recognizing who they are, what they might know already, and what they don't know
- Done well, annotation can help explain and facilitate the viewing and interpretive experience
- It is the challenge of creating a layer of user assistance and user insight
- How can you maximize the clarity and value of engaging with this visualization design?

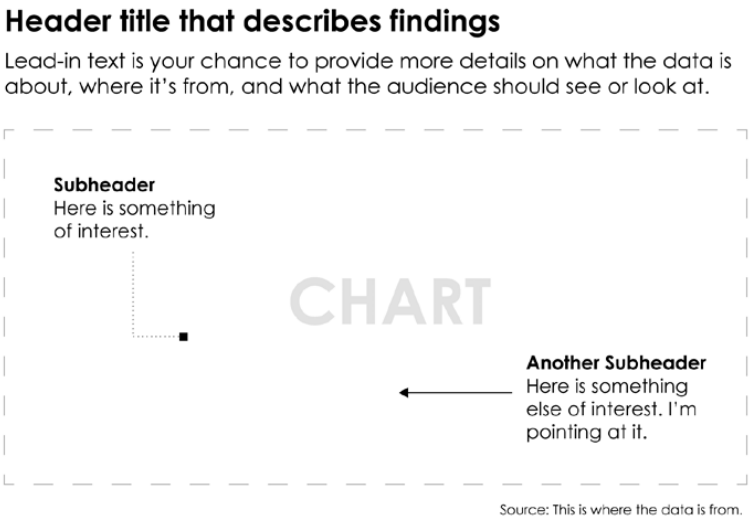
Highlighting

- When you highlight elements, it is not always obvious why, especially when readers aren't familiar with the data
- Annotation within a visualization can help clearly explain what a visualization shows
  - What is that outlier?
  - What does that trend mean?
- This might be left to text outside of a visualization, but when you put explanations within a graphic – as an additional layer of information – the visualization is self-encapsulated so that it's useful on its own

Visual Hierarchy

- Like everything discussed so far, annotation follows a visual hierarchy
- You have headers, subheaders, subsubheaders, and explanatory text
- As shown next, size, color, and placement dictate how much attention annotations receive

Annotating a Chart



Source: Yau (2013)

Header

- The header is typically printed with larger and bolder fonts to set the stage or to describe what people should see or look for in the data
- If the header is small and blends with everything else, people might skip it and look straight to the more visual elements
- A descriptive title also helps. For example, "Rising Gas Prices" says more about a chart than just "Gas Prices"
- The former presents a conclusion immediately, and readers will look to the chart to verify and see details
- The latter leaves data interpretation to readers and places them in the exploration phase
- Then again, this might be your goal, so describe accordingly

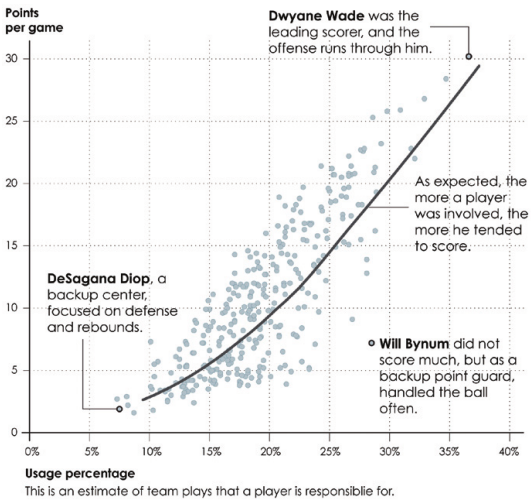
Lead-in or Introduction

- Lead-in text, like the header, is used to prepare readers for what a chart shows, but in further detail
- The text is typically smaller than the header and expands on what the header declares, where the data is from, how it was derived, or what it means
- Basically, it's information that might help others understand the data better but often doesn't directly point to specific elements
- Introductions are a really important instructive elements to explain the project's background and context, describing the background motivation and what your intentions are in terms of how it should be used

Guiding

- To explain specific points or areas, you can use lines and arrows and use annotation as a layer on top of a chart
- This places descriptions directly in the context of the data so that a reader doesn't have to look outside a graph for additional information to fully understand what you show
- In the next Figure, dark circles and pointers highlight specific players, and lines connect annotation to dots for the lowest scoring player with the lowest usage percentage, DeSagana Diop, and the highest scoring player with the highest usage percentage, Dwyane Wade
- The point for Will Bynum, who somewhat strays from the trend, is also highlighted and annotated. There is also a pointer for the trend line and an explanation of usage percentage, which isn't common knowledge for most

Annotated Plot

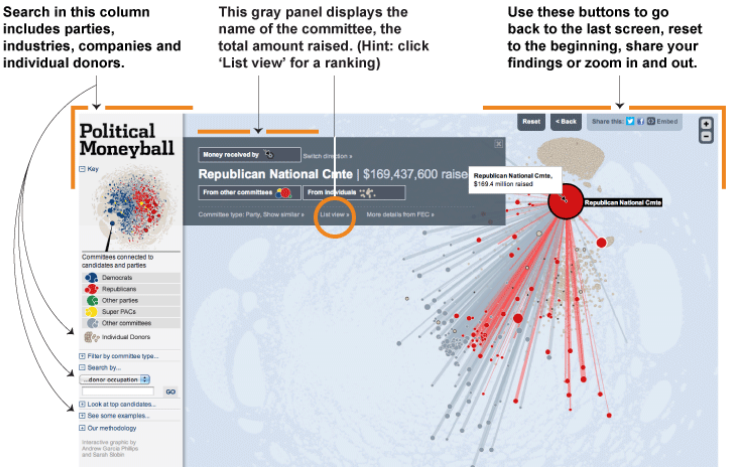


Source: Yau (2013)

User Guides

- User guides: While intuitive accessibility is stated as an overall goal, many projects often warrant further explanation, particularly with interactive pieces and those that have inherently complex subjects or frameworks
- In this next project, titled Political Moneyball and created by the Wall StreetJournal, we see a demonstration of exceptional care for the audience's understanding of how to optimize this visualization's use
- Not only does it include thorough written annotation and labeling to help users understand all the features of this incredibly immersive tool, but there is also a video tutorial to offer that extra degree of support

Political Moneyball



Source: Kirk (2012)

Labels

- Labels: In the interactive section, we discussed the potential of labels to reveal extra details about data values
- As we see in the previous project, labeling is an incredibly simple but useful device to help explain matters
- Often, these are hidden and interactively revealed through selection or by hovering
- Labeling of axes and data types is a must

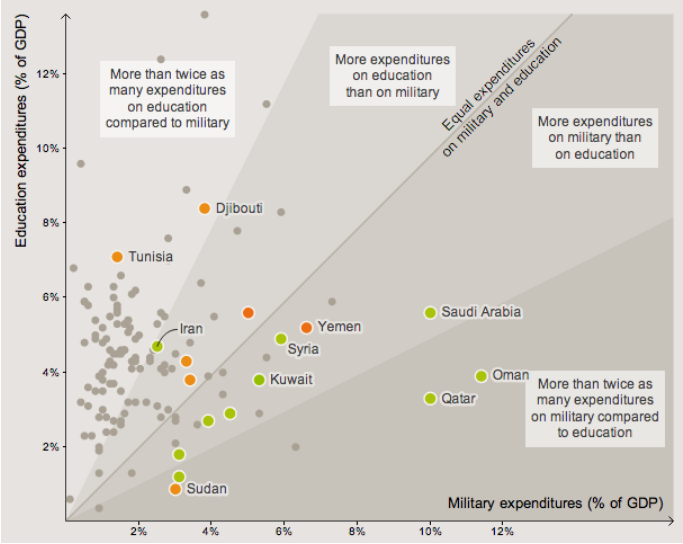
Captions and Narrative

- Captions and narrative: In addition to the potential use of the title to offer a key headline, sometimes you may wish to surface important insights and findings to help fast-track the reader's interpretation process
- You might draw out the good and the bad or maybe the expected or unexpected
- You should also consider the potential value, in certain projects, of the "what next?" question
  - what should the user do with this information?
  - what actions need to be taken?

Visual Annotation

- Visual annotation: Annotation goes beyond just written explanations and we should consider how to use chart or graphic devices to help draw out important insights visually
- Simple options include features such as gridlines, axes labels, and tick mark
- In an example we have seen earlier, reference lines and background shading is used effectively to help the reader achieve distinction between different tiers of interpretation, as you explore the relationship between what countries spend on education and the military

Expenditures



Source: Kirk (2012)

Legends and Keys & Units

- Legends and keys: Always explain the use of color schemes or the varying size of shapes in terms of their categorical or quantitative representation
- Units: You should include details of the units of values being displayed to ensure you don't create ambiguities and potential misinterpretation
- As with many of these annotated features, this is an obvious requirement, something we've had drilled into us since our school days, but you'd be surprised how often they can be left out

Data Sources & Attribution

- Data sources: It is vital to include detailed references about from where you have accessed your data or any other sourced element (such as imagery)
- Where you have chance to offer a more detailed narrative, you may wish to explain what treatment you have applied to the data in terms of its quality or analytical transformation
- Attribution: Don't forget to acknowledge those who have either contributed directly, influenced the construction of the design, or those people whose work has acted as a source inspiration

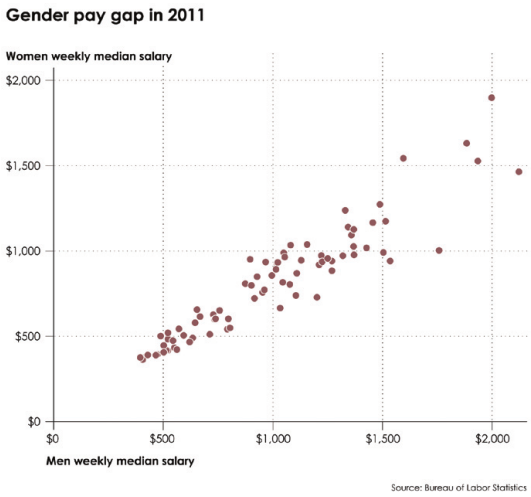
Explain Statistical Concepts

- If a large proportion of your audience is unfamiliar with statistical concepts, you can annotate to explain or help them relate
- The descriptions in the previous scatter plot of basketball players are an example
- They don't just point out Dwyane Wade, DeSagana Diop, and Will Bynum
- They also help explain what the corner positions, as well as a partial outlier, on an x-y plot mean so that readers can infer what positions in the middle represent
- The pointer for the trend line is a description of correlation

Gender Pay Gap

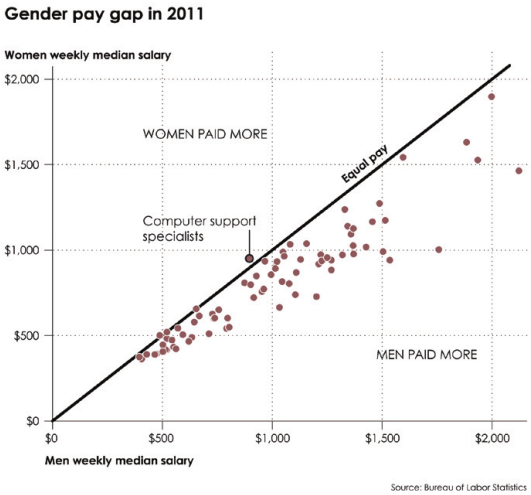
- Following is another scatter plot, but it focuses on the gender pay gap in the United States, based on median salaries, according to the Bureau of Labor
- Each dot represents a profession, and men's median salary is plotted on the horizontal axis versus women's median salary on the vertical
- Without annotation, it's clear there is an expected upward trend between the two
- With professions where men tend to make more, women tend to make more, too
- If you look closely, you can also see that the dots tend toward the horizontal axis, which means men tend to make more with the same occupation

Gender Pay Gap I



Source: Yau (2013)

Gender Pay Gap II



Source: Yau (2013)

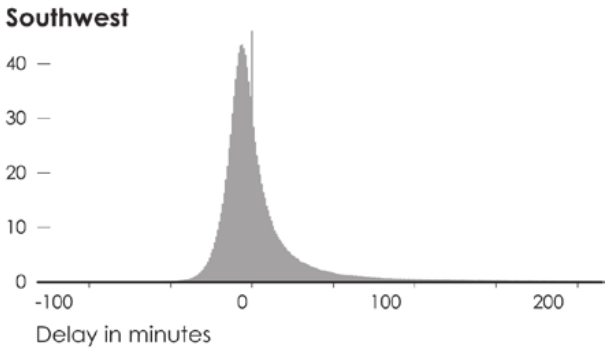
Explanatory Annotations

- The annotated chart in the second Figure makes the pay difference clearer
- A diagonal line through the middle represents equal pay, which is marked as such
- Dots below the line are jobs where men make more than women, and dots above the line are where women tend to make more
- These areas are also labeled
- The annotation explains how to read the scatter plot and what the data means

Distributions

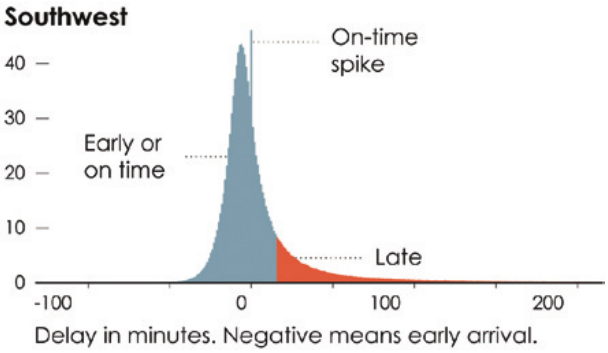
- Distributions are another challenging concept
- People have to understand skew, mean, median, and variation, and that observations are aggregated across a continuous value scale when visualized
- For example, it is common for people to interpret the value axis of a histogram as time and the count or density on the vertical axis as a metric of interest
- This leads to confusion, so it is useful to explain the various facets of a distribution

Distributions I



Source: Yau (2013)

Distributions II

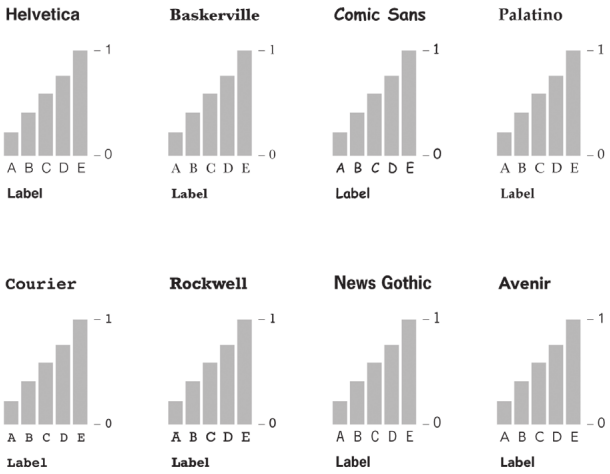


Source: Yau (2013)

Typography

- There have been plenty of polls and questionnaires that ask what the best typeface is for visualization, but there's always a ton of variability, and there's never any consensus
- This might be because taste in typefaces has a lot to do with personal preference
- Nevertheless, it's worth exploring various fonts for labels and annotation, outside of software defaults, which are generic and less refined
- General rules about print and screen typography still apply

Example: Typography



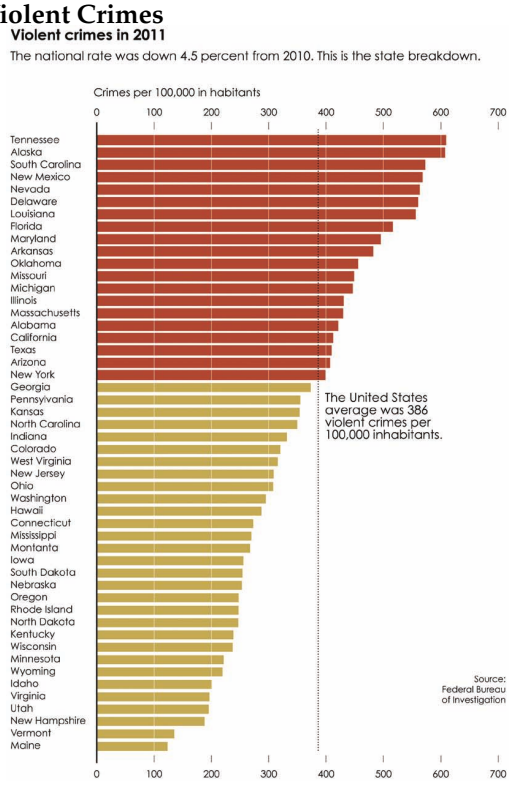
Source: Yau (2013)

3.5 Math

Do the Math

- After you get data, the natural first step is to visualize it directly, but after that, it might be useful to do some math for a different point of view
- This can shift focus toward something more interesting in the data and in some cases, avoid guesswork as readers try to interpret your graphics
- For example, summary statistics, such as mean or median, can serve as a quick point of reference or to provide a sense of scale
- The next figure provides an example

Violent Crimes



Source: Yau (2013)

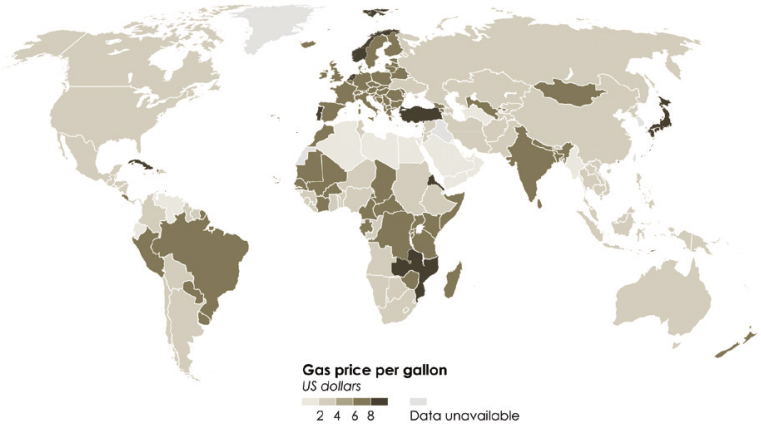
- Violent crime rates for each state are shown, and bars are colored based on whether they are above the national average
- The distributions of rates isn't especially complex in this example, but it helps you get a sense of where each state lies relative to the national average

More Math

- As an additional step, you can transform the data based on a reference point, rather than just show it in the context of the raw data

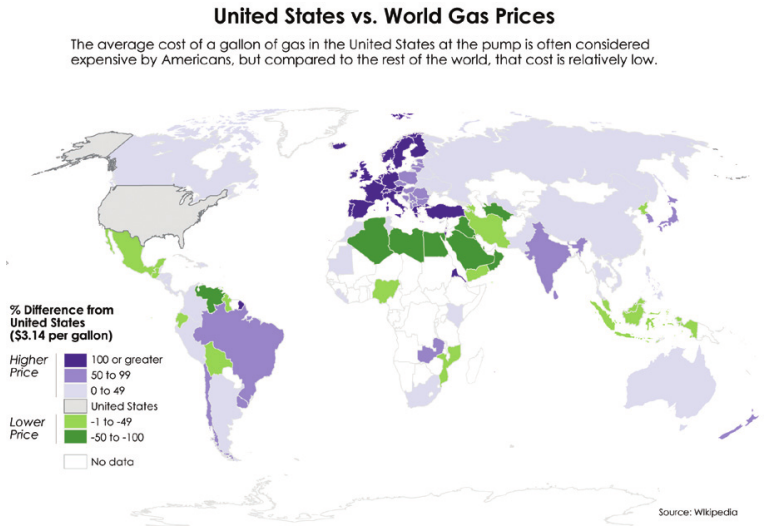
- The next Figure shows global gas prices, which you saw previously, relative to average gas price in the United States
- Purple indicates higher gas prices, and green indicates ountries where gas prices were lower
- The two maps show the same data but tell different stories via subtraction and division
- The first map focused on worldwide comparisons, whereas this map provides a simple connection between the data and U.S. readers

Gas Prices I



Source: Yau (2013)

Gas Prices II

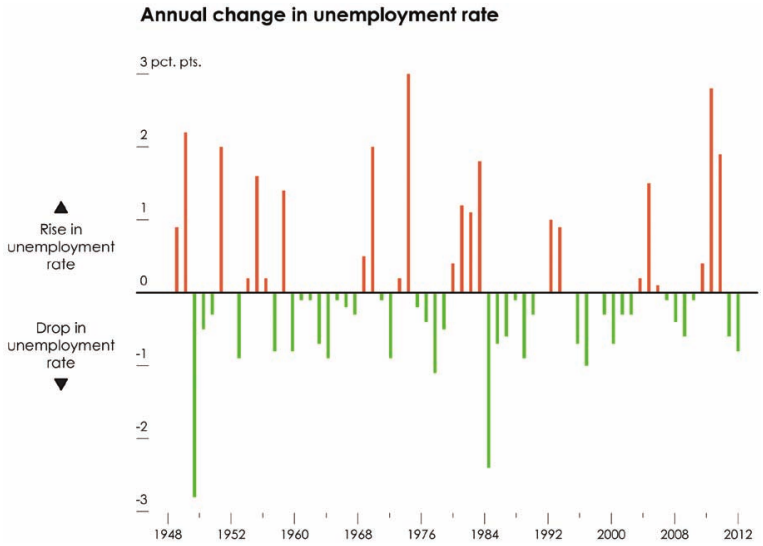


Source: Yau (2013)

Unemployment Rates

- What about the Figure that shows the unemployment rate over time
- Maybe you're more interested in annual changes than you are monthly unemployment
- From each rate, subtract the rate that came the year before, as shown next

Unemployment Rates

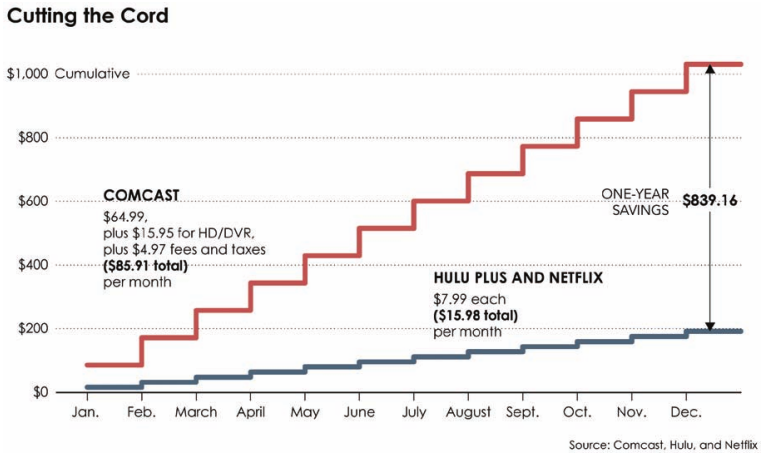


Source: Yau (2013)

Aggregates

- You can take it the other direction, and add values, as shown next
- A step chart shows the monthly cumulative cost of cable over a year versus the modest cost of Hulu Plus and Netflix
- An aggregate at the end shows total annual savings if you were to switch to the latter.

Comcast vs. Netflix plus Hulu



Source: Yau (2013)

Math Helps Tell Stories

- Straightforward math operations can help you see your data from a different angle or bring focus to a graphic
- Of course, the more statistics you know, the better you can process and analyze your data, which in turn can lead to more informative graphics
- Account for how people might interpret a graphic, and if they have to do math in their head to make inferences, it might be worth the effort to do the math for them and translate the results visually

3.6 Arrangement

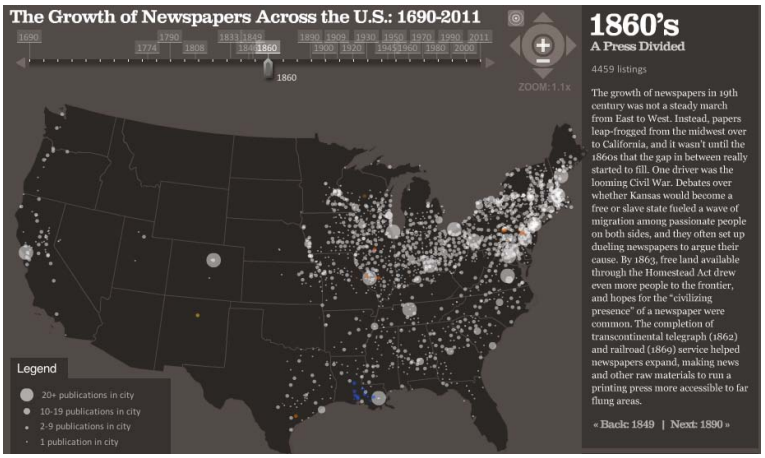
Arrangement

- For our final layer, we need to consider how to arrange our design in terms of the layout, placement, and organization of all visible elements
- How can we piece everything together most effectively?
- As we've just discussed in relation to annotation, our intention with the arrangement and architecture of our design is to deliver as intuitive an experience as possible
- The level of intuitiveness and smooth access into the subject matter is strongly influenced by the logic and implied meaning behind the arrangement of our chart elements, the interactive features, and annotation devices

Reduce Effort

- The key overall aim is to reduce the amount of work the eye has to undertake to navigate around the design and to decipher the sequence and hierarchy of the display
- For the brain, once again, we're looking to minimize the amount of thinking and "working out" that goes on
- We therefore need to carefully consider the choices we make around the size, positioning, grouping, and sorting of all that we show
- As with all visualization design layers, we need to be able to justify the decisions we make about every visible property presented

Example: Growth of Newspapers



Source: Kirk (2012)

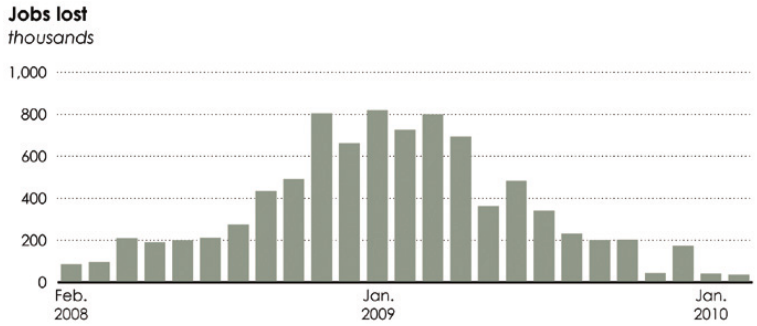
Example: Growth of Newspapers

- Observe the positioning of the chapter navigation slider across the top, the size of the space afforded to the main map display, the narrative found on the right-hand side, the proximity of the legend to the data, and the location of the pan and zoom device
- all these decisions are very deliberate and designed to maximize the logic and meaning behind the layout of this project's data, its interactive features and annotated elements

Geometry

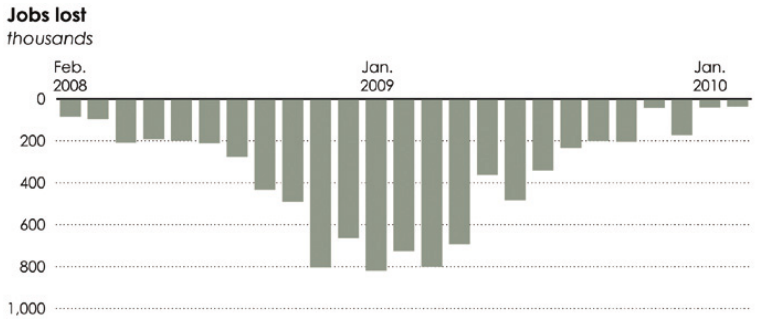
- Context can also affect your choice of geometry
- For example, the Bureau of Labor statistics releases monthly estimates for number of jobs lost and gained
- The next Figure represents jobs lost between February 2008 and February 2010
- More jobs were lost than gained every month during this period
- The taller the bar is, the more jobs that were lost on the corresponding month.

Job Loss I



Source: Yau (2013)

Job Loss II



Source: Yau (2013)

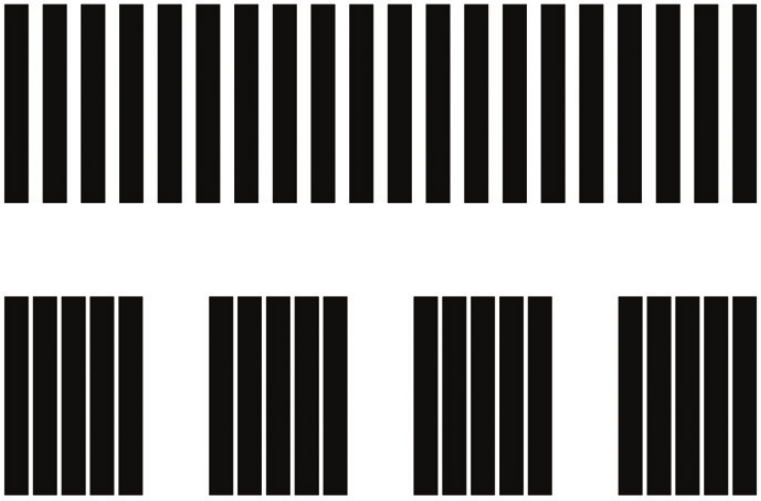
Geometry in Context

- The chart with values in the positive makes sense, but consider the context the chart is usually presented in
- People expect to see bars in the positive for jobs gained and in the negative for jobs lost
- However, the coordinate system in the first Figure would put jobs gained in the negative
- Negative jobs lost means new jobs
- So instead, it's more intuitive to frame jobs lost as negative values
- It makes more sense to show something lost moving downward, when that something is looked at negatively
- On the other hand, decreased weight, when the goal is actually to lose weight, might work better on the positive side of the axis

Negative Space

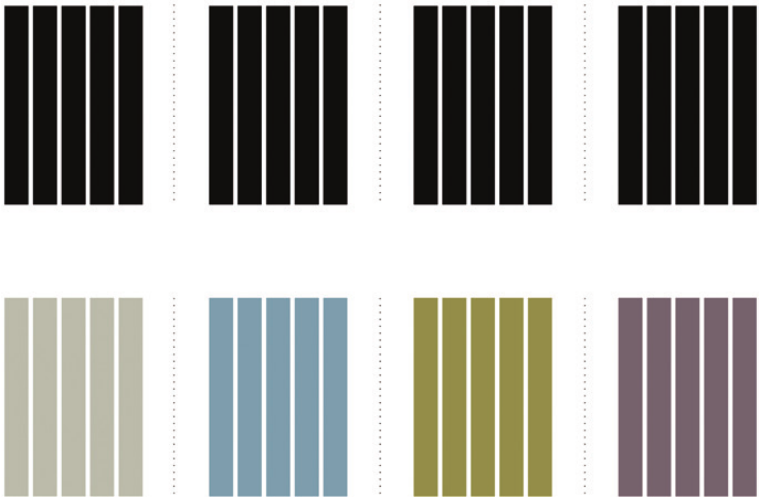
- Clutter is the enemy of readability
- A lot of objects and words packed into a small area can make a visualization confusing and unclear, but put some space in between and it's often a lot easier to read
- You can use space to separate clusters within a single visualization, or you can use space to divide multiple charts, so that they are modular and don't all run together
- This makes a visualization easier to scan and mentally process piece-wise

White Space I



Source: Yau (2013)

White Space II

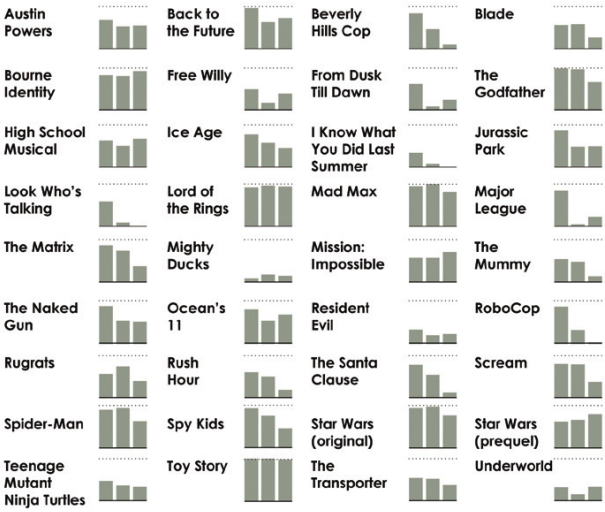


Source: Yau (2013)

Movies Revisited I

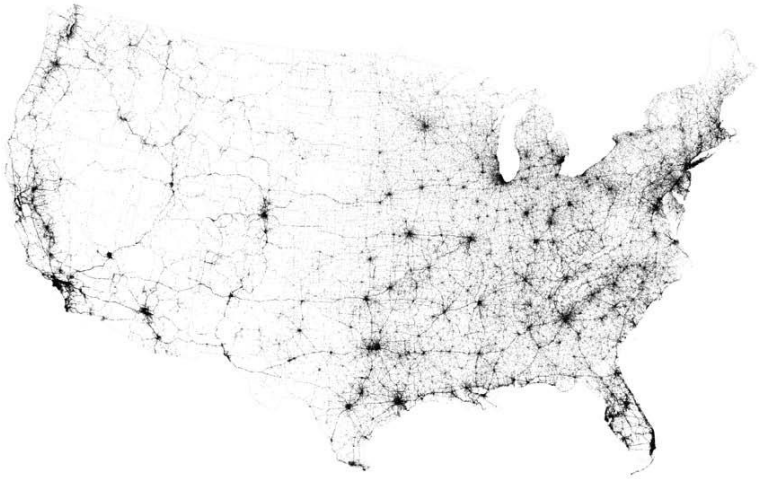
Source: Yau (2013)

Movies Revisited II



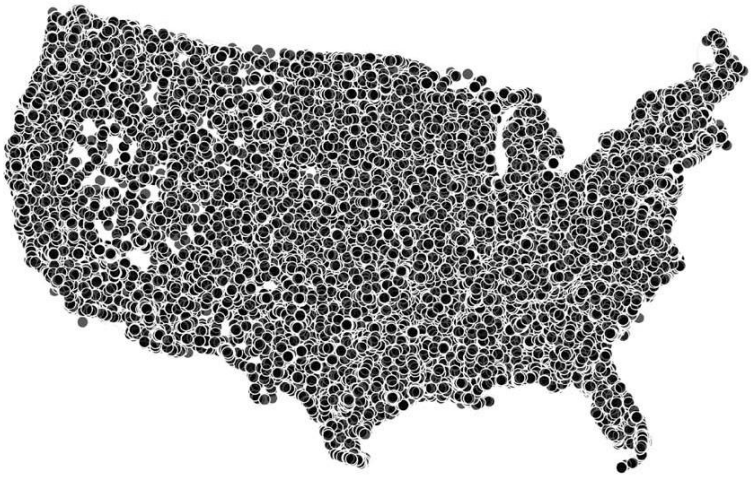
Source: Yau (2013)

Fatal Accidents Revisited I



Source: Yau (2013)

Fatal Accidents Revisited II



Source: Yau (2013)

Fatal Accidents

- Because small dots are used in the first version, it's easier to see the pattern of roads and city centers
- The negative space in between points help show where there are no roads or where fewer people drive cars
- Places where there is no data is just as important as the places where there is data
- On the other hand, the second version uses large circles that are relatively large compared to the size of the United States and the total number of crashes during the selected time period
- There is practically no negative space, so roads and city centers are hidden by the data, and you only see country boundaries
- Without a sufficient amount of negative space, the visualization is useless

4 Tutorial

Assignment 5.1: Process

- Analyze the different process models
  - Find commonalities and differences
- What role do human aspects play?
- Come up with a unified process model that fits your work flow
- Deliverable:
  - Monday, 26.6., 18:00, learnweb
  - Monday, 26.6., in the course

Assignment 8.1: Exam Questions

- English or German?
- What kind of question do you expect in the exam?
- Design sample questions
- A discussion thread for exam questions has been opened in the LearnWeb

References

Literatur

Kirk, A. (2012). *Data Visualization – A Successful Design Process*. PACKT Publishing, Birmingham.

Yau, N. (2013). *Data Points – Visualization that means something*. Wiley.