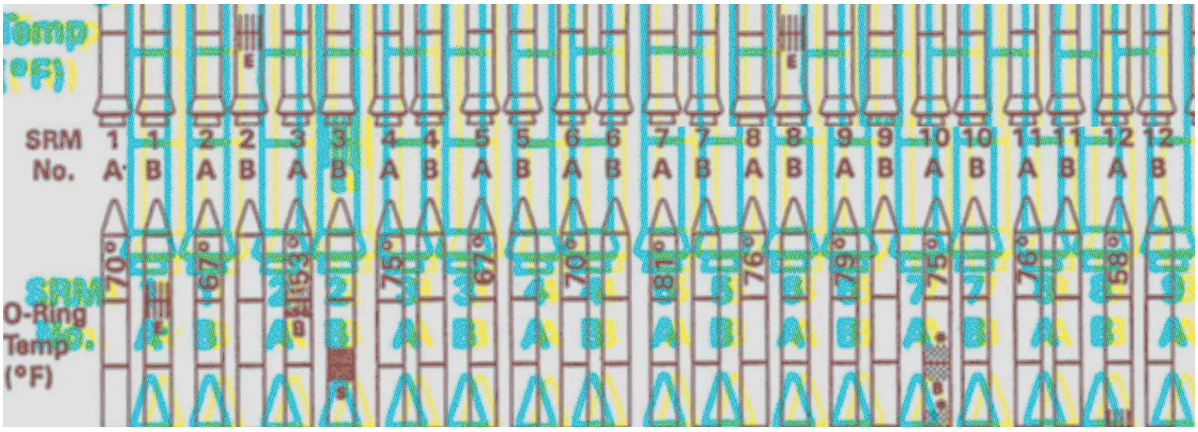
Data Visualization

Design and Redesign in Data Visualization

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Visualization is now a mass medium. It's not quite Hollywood, but information graphics have millions of viewers, awards ceremonies, and even their own celebrities with tens of thousands of Twitter followers. More important, from the perspective of journalism, is that data visualization is an essential part of the communication process. Today, a data-driven story without a chart is like a fashion story without a photo.

Along with the glitter and popularity, visualization has attracted something else: popular criticism. It's happening at a small scale; we don't yet see infographics reviews in the *New York Times* Arts section. Nonetheless, when a striking visualization comes out, it's not unusual to see commentary and controversy on the web, moving from blogs to Twitter to Facebook. That level of critique comes with the territory for any popular medium of communication, and shouldn't be a surprise.

But the process of giving and even receiving visualization criticism does turn out to hold surprises. It's not just that visualization is so new, or that criticism can stir up emotions in any medium. As we'll discuss, the fact that visualizations are based on transforming raw data means that criticism can take forms that would be impossible for a movie or book. Our goal in this essay is to think through the issues involved in public visualization criticism, especially criticism based on direct redesigns.

Redesign as criticism

We'll begin with a famous critique from a famous critic. Edward Tufte, in his landmark book Visual Explanations [1], wrote about the decision process that led to the explosion of the Space Shuttle *Challenger* in 1986. Engineers and government officials alike used crude hand-written tables and diagrams to reason about the situation and communicate their decisions. Tufte provides a masterly analysis of problems both in the diagrams and the mental process they

reflected.

An essential part of Tufte's argument is that design mattered: the data was sufficiently conclusive that with clear communication based on clear thinking, the shuttle would never have launched. (Depressingly, he makes the case that even the report produced after the failure embodied muddled thinking.) To prove his point about design, Tufte produced a redesign, a new diagram that's a paragon of clarity compared to the original tables produced by engineers or the charts seen in the official government investigation.

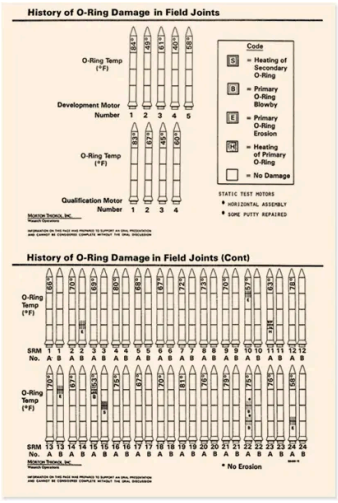
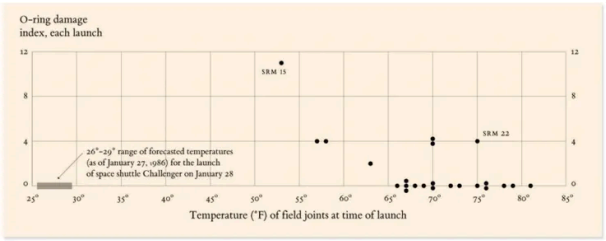


Chart shown to the presidential commission investigation on the Space Shuttle Challenger in 1986. The chart shows the history of O-Ring failures

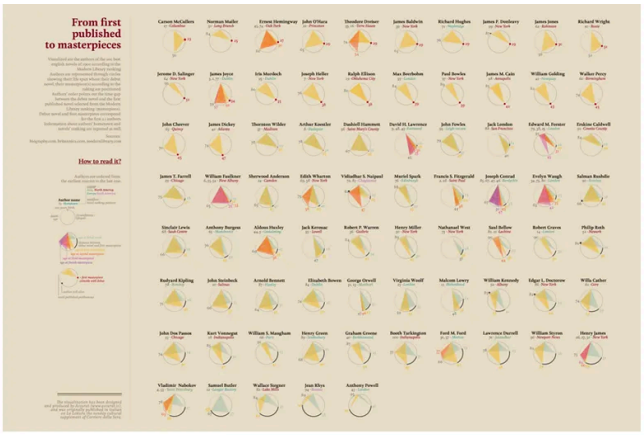


Edward Tufte's redesign of the same chart showing O-Ring failures.

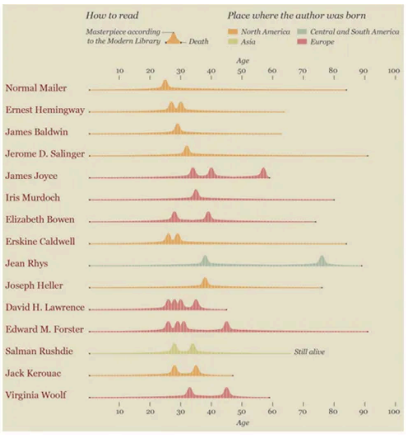
Figure 1. Left: the chart shown to the presidential commission investigating the Space Shuttle Challenger in 1986, showing the history of O-ring failures. Right: Edward Tufte's redesign of the same chart showing O-ring failures.

To demonstrate how the key variables could be directly compared, Tufte produced the scatterplot in the figure above. In this chart, the data seems to speak for itself: an unmistakable illustration of the danger of low temperatures, with the only cold-weather launch appearing as a clear outlier. The scatterplot redesign is one part of long and subtle analysis, but it has pride of place. "Had the correct scatterplot or data table been constructed," concludes Tufte, "no one would have dared to risk the Challenger in such cold weather."

The tradition of critique by redesign is, if anything, growing in popularity. Here's very recent example. Giorgia Lupi, of Accurat, created a diagram of the output of famous authors, visualizing the dates of their masterpieces in the context of their lifespans. Her chart was an unusual combination of "small multiple" polygons that encoded several different publications for each author. Alberto Cairo, a professor at University of Miami, used straightforward linear timelines based on the same data. The resulting side-by-side comparison [2] makes it extremely easy to compare the two encoding methods.



Accurat's visualization of the output of famous authors.



Alberto Cairo's redesign of the same graphic.

Figure 2. Left: Accurat's visualization of the output of famous authors. Right: Alberto Cairo's redesign of the same graphic.

The technique of "critique by redesign" in some ways works uniquely well in data visualization. A movie critic can't remake a movie. An art critic can't ask the subject of a portrait to sit for a second time. A book critic may be able to rewrite a sentence, but not a whole book. But with data visualization, if there's access to the underlying data set, and the data is not too complicated, it's feasible to create at least a rough redesign.

Of course, just because this technique is feasible doesn't mean it's a good thing. The implications of critique by redesign are surprisingly complex, and we'll spend much of this essay unpacking them. But even these initial examples show some of the obvious advantages and drawbacks.

First, some advantages. A redesign is — or should be — intellectually honest, since it's using the same data. It also allows direct visual comparison; when a visualization is described in words, something is always lost in translation. Enabling direct, honest comparisons leads to the second key advantage, which is that redesigns are convincing in a democratic way. Instead of a verbal appeal to authority ("This design is flawed because I say so") a side-by-side comparison lets the viewer decide.

At the same time, redesigns can be problematic. Tufte had one huge advantage over the creators of the diagrams used to make the space shuttle decision: he knew the answer to the question they were considering, and he knew exactly which variables mattered. His redesign makes an open-and-shut case at first glance. Stare a little longer, and you realize that the bulk of the visual effect rests on just one data point, the dramatic outlier at the upper left corner. Remove that, and the trend takes a far more muted form. Would it have convinced a stubborn politician to call off the launch?

Indeed, is it really a good idea to give so much weight to a single outlying data point? Clearly in the case of the *Challenger* it would have been. As a general rule, though: not always. One wonders… Had the launch gone off without incident, could someone with Tufte's skill have created, from the same data, an equally convincing graphic about the wisdom of ignoring outliers?

Tufte also took a second shortcut. His scatterplot picked out the exact data dimensions that — after the fact — were known to be decisive. It leaves out variables such as the location or type of O-ring problems. In hindsight, that information was irrelevant to the analysis, but of course there was no way to know that at the time. Adding that data to the chart would have made it more cluttered and ambiguous. In fact, it's all too common to see critics simplify in ways that help their cases. Cairo's redesign of Lupi's timeline is airy and elegant… but only shows 50% of the data in the same space. In these particular cases, the shortcuts don't seriously undermine the critics' main points, but they do raise some room for doubt.

Perhaps the biggest problem with redesigns, however, is their removal of context. Design is compromise. Anyone who's ever designed a logo, made a movie, or built a house, knows that the final product reflects a series of mostly hidden goals and constraints. To redesign without knowing these constraints — the client insisted on pink! the lead actor broke his ankle! the zoning board was insane! — is, in some sense, unfair.

In the case of visualizations, this context can range from differences in strategy and goals to tactical constraints. As Tufte discusses, *Challenger*'s engineers were well aware of the risks of the flight and had recommended against launching. However, political pressure around the timing may have made the difference in the decision. Despite his conclusion that the right scatterplot or data table would have made the difference, the best design in the world might not have changed the decision. In the case of Cairo's redesign, the relative weight placed on legibility versus aesthetics and novelty may have been different.

It should be clear by now that there's no such thing as a simple redesign.

Redesign in public

In 2004 the U.S. electorate was dramatically divided between two presidential candidates: President George Bush from the Republican Party and John Kerry from the Democratic Party. Throughout the campaign, election maps tracked the split, with "red" and "blue" states representing locations whose residents predominantly voted for the Republican Party (red) or Democratic Party (blue). A major flaw of the red-blue map was the impression it gave that the Republican Party had a much wider following than it actually did. Because of the large geographical size of many states in the central and southern United States, which predominantly supported the Republican candidate, the color-coded map ended up as a sea of red. The impression was of a country that overwhelmingly voted Republican. In other words, the map failed to take into account the population distribution of the U.S. It did not capture the fact that population in red states is, on average, significantly lower and less dense than that of blue states (more Democrat voters tend to live in large cities).

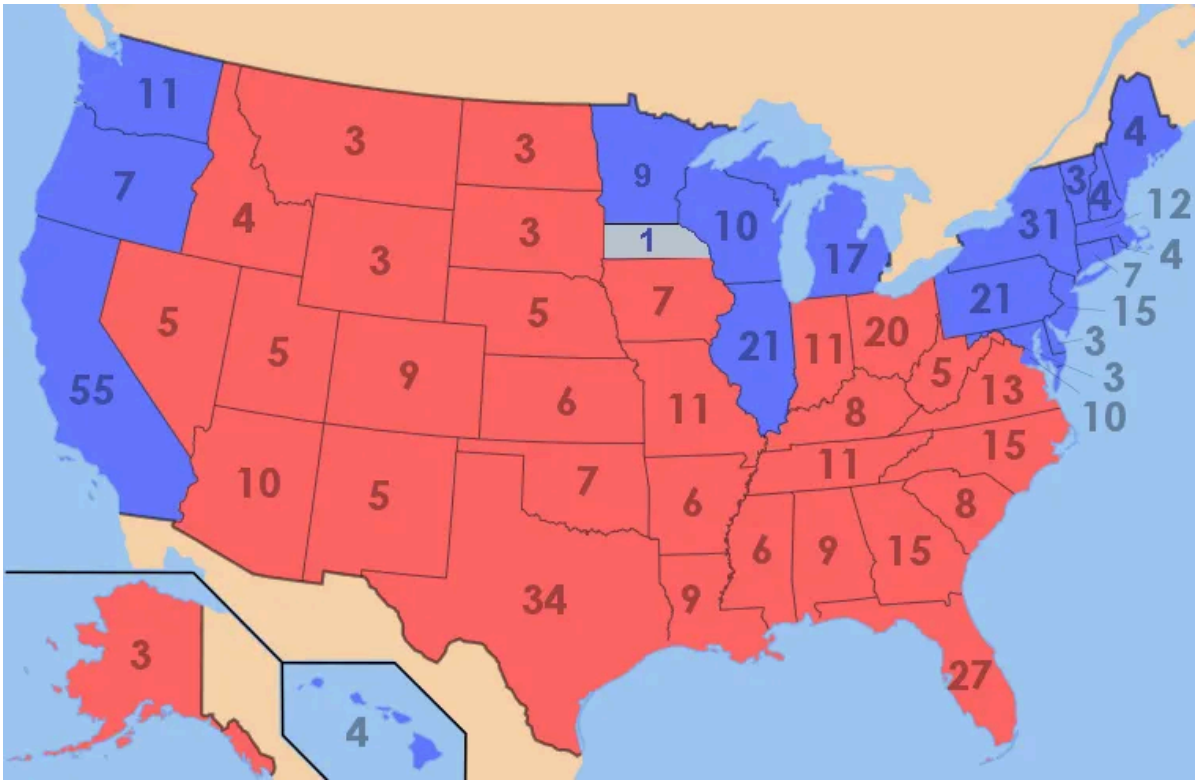


Figure 3. Red and Blue Map of 2004 US Presidential Election. (Election maps from Wikipedia [4])

This visual puzzle generated a public quest for more effective ways of displaying U.S. election data. Data scientists, journalists, and visualization experts among others produced a series of maps that tackled different angles of the problem. County-based maps broke down states into smaller units so that pockets of Democratic voters could be seen in Republican states. “Purple haze” maps blended red and blue reflecting the percentage of Republican and Democratic votes in each location. Cartograms, a more exotic technique from the world of data visualization, distorted geographical areas by scaling counties and states according to their population.



Purple county map showing the proportion of Republican (red) and Democratic (blue) votes.

Purple cartogram sizing counties by population.

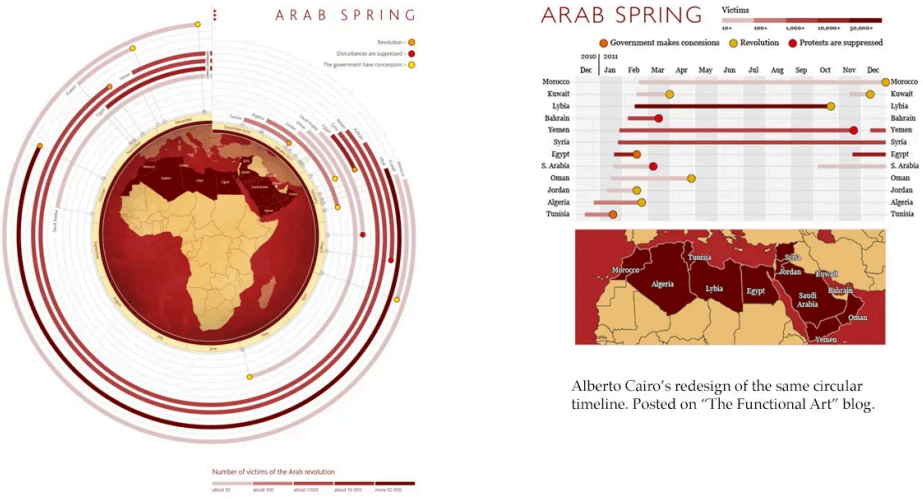
Figure 4. Left: purple county map showing the proportion of Republican (red) and Democratic (blue) votes. Right: purple cartogram sizing counties by population.

This process of data analysis and map creation happened in public, with different versions of the “Red and Blue” map appearing every few weeks. There was no single right answer to speak of. Each map represented a series of tradeoffs and biases. In aggregate, though, these maps constituted a dialog; a powerful and healthy new way of engaging in a public exchange of ideas

about a country's identity and direction. Perhaps just as important, these activities evolved in a fairly collaborative manner. Instead of trying to explicitly redesign each other's maps, practitioners were building on each other's work to get to a better visual encoding of the data. It was a collaborative activity fueled by the need to visualize and understand the data better.

Unfortunately, public re-creations of data visualization projects may not always lead to such a uniformly positive reaction. There have been occasions where redesigns met with significant backlash. Take, for example, a second redesign done by Alberto Cairo in February 2015. As with his critique of Giorgia Lupi's work, Cairo took a radial plot (a timeline of the Arab Spring timeline, created by Alexander Katin and Kir Khachaturov) and "unrolled" it to linear coordinates.

After Cairo blogged his redesign, responses came fast and furious, falling mostly along two opposing lines, one arguing for the importance of aesthetics in the original graph, the other contending that data legibility was dramatically improved in the redesigned solution.



Timeline of Arab Spring events in North Africa, by Alexander Katin and Kir Khachaturov.

Alberto Cairo's redesign of the same circular timeline. Posted on "The Functional Art" blog.

Figure 5. Left: timeline of Arab Spring events in North Africa, by Alexander Katin and Kir Khachaturov. Right: Alberto Cairo's redesign of the same circular timeline, posted on "The Functional Art" blog.

> *"@albertocairo The circle is meant to show a yearly cycle, right?"*
>
> *"The distortion caused by the circular layout makes the timeline of Tunisia looks shorter than that of Yemen, when in fact the period depicted for Yemen is much shorter"*
>
> *"I'm siding with @blprnt rather than @albertocairo in the great circular timeline debate of 2015."*
>
> *"I'm with the straight line version, if the purpose is clarity. To read the circles I need to perform, like, a zillion eye movements as a I move along the scale."*

Sample quotes from Twitter. In addition to the passages above, there were some more heated Tweets as well (all caps and expletives).

Public redesigns that are broadcast to thousands, potentially millions of people around the world are a new phenomenon, a product of the social media era. Such reach and immediacy can have both benefits and disadvantages. On the plus side, it is easy and cheap for redesigns to

be widely seen and discussed by the data visualization community. On the other hand, because they take place on social media, such redesigns automatically collapse multiple audiences into a single context. It is a stark departure from traditional design-studio-based peer crits where colleagues share the context and intent of a piece, know the person whose design is being critiqued, and are physically present. Online, public redesigns can feel faceless and less personal, quickly inviting animosity and bitterness.

In the Cairo example, the initial context was pedagogical: his student had asked about radial graphs and Cairo was hoping to illustrate the effectiveness of linear versus radial solutions. Once on Twitter though, the conversation took on a different tone, including questions about aesthetics, Cairo's authority in the subject matter, the importance (or lack thereof) of the data shown, the role of design, etc. On the one hand, this broadening of topics is something to aspire to during a critique. On the other, the antagonism that sometimes accompanies such exchanges would be better left out of the process altogether. But how to balance these tradeoffs: reach vs. context? And how to optimize so that most of the discussion around a redesign is productive?

Redesign: bridging the two cultures

The field of visualization sits at the intersection of two very different intellectual traditions. On one side of the family, visualization traces its roots to art and graphic design. On the other side, it's descended from computer graphics and the tradition of scientific experiment. It's worth taking a step back and describing some of the morés and norms in each field, and how they conflict in the case of visualization criticism.

An essential way that literary and artistic fields move forward intellectually is *criticism*. Colloquially, "criticism" implies negativity, but of course there's a much richer tradition in the arts and humanities. As Bardzell puts it, "*Speaking generally, criticism refers to an expert of a given domain's informed exercise of judgment; familiar examples include film and literary critics, architectural criticism, and even a qualified Master of Wine's ability to judge wine.*" [3] One reason to emphasize this definition is to avoid a trivial misunderstanding: an endorsement of "visualization criticism" isn't a call for general negativity.

In the design community, there's a particular flavor of criticism that is common: the design critique. Unlike more abstract or philosophical literary criticism, a classic "crit" usually has the goal of improving a work in progress. A key part of the critique process is the social context: the fact that it's a group of colleagues having a serious, high-level conversation. It's rare for a crit to be held in public; they're more commonly found in studios and schools, comprised of professionals and students — people dedicated to their craft, with a shared knowledge of the context for a design, exercising careful judgment.

In science, we see something different. Science seeks to remove human judgment from the process of testing hypotheses. (Judgment certainly survives in funding and publication processes, but that's a separate story.) A hypothesis isn't even considered scientific unless it's falsifiable, that is, there's a mechanical recipe for showing it's wrong. The gold standard for a new medical treatment, after all, isn't the opinion of a committee of doctors, but a double-blind experiment — ideally, an experiment that is replicated successfully by more than one group.

In the case of computer graphics, one of the scientific ancestors to data visualization, we see a series of test images that have become de facto standards. For instance, researchers who work on 3D rendering often start with a particular teapot model. Scholars of image compression and enhancement have for decades used the (notorious) "Lena" *Playboy* portrait. The goal is to apply new techniques and ideas in a well-understood context, so anyone may perform a direct comparison with previous work.

Comparing these traditions explains some sources of confusion in criticism by redesign. Seen from a tradition where critique largely happens in private, a public redesign can feel unduly personal and exposed. A critique that happens in public, available to anyone who clicks the right link, loses much of the context necessary for thoughtful commentary. Meanwhile, from the point of view of an experimental scientist, the necessary human — and ultimately subjective — professional judgment that is involved in evaluating a redesign may seem like a cheat. We've seen evidence of both these reactions from practitioners in the field.

Despite these issues, the method of "critique by redesign" may be just the blend that will help advance the field. The truth is that perceptual psychology and related sciences can provide some guidance for visualization, but are nowhere near advanced enough to completely answer all real-world design questions. Ultimately, human judgment remains essential to the process. And while the lack of context and collegiality can make a public critique problematic, we believe there are "rules of engagement" that can bring out the best in the process and avoid some of the worst pitfalls.

Rules of engagement

Design is not a science. But "not a science" isn't the same as "completely subjective". In fact, the critique process has brought discipline to design for centuries. For visualizations which are based on an underlying shared data set, there's an opportunity for an additional level of rigor: to demonstrate the value of a critique through a redesign based on the same data.

Criticism through redesign may be one of the most powerful tools we have for moving the field of visualization forward. At the same time, it's not easy, and there are many pitfalls, intellectual, practical, and social. How can we use the tool of criticism to best advantage, with awareness and respect for all involved? Here are some suggestions, which fall into three categories: maintain rigor, respect for designers, and respect for critics.

1. Maintain rigor

As with a scientific experiment, it's important to know the reason for a redesign — what is being "measured", in a sense. There are many possible goals for a visualization: to communicate data, to spur conversation, to persuade, to draw in viewers, to create an aesthetic experience. A critic who creates a redesign should be explicit about the goal — and the fact that they may be interested in a different goal than the designer. This is especially important on the web, where people may stumble on the result without knowing any other context.

Second, critics must be honest about any simplifying assumptions. If a redesign shows less data than the original, that should be mentioned up front. Otherwise, there's a danger that any

perceived simplicity of a redesign is really just the result of a reduction in data.

Part of maintaining rigor is acknowledging situations where professional judgments don't agree, and finding ways to come to an understanding. Sometimes people will look at a side-by-side comparison and come to opposite conclusions. (We saw this in the radial timeline redesigned by Alberto Cairo, for example.) The first step is to have a conversation about the source of the disagreement. Very often it turns out that different professionals have different criteria for success for a visualization, or have different goals in mind; clarifying these is extremely useful to the field. Other times, however, people simply have different intuitions about clarity or legibility. In these situations, it may make sense to turn to a scientific experiment. This should not be viewed as a failure of criticism, but rather a success: a crisp, testable scientific question is a rare commodity.

2. Respect the designer

All redesigns have the potential to seem adversarial, as if the critic is pointing out flaws in the designer personally, asserting their own superior skills, or even, as in Tufte's redesign, assigning some blame for a disaster. In the age of viral links, the effect is doubled: seeing negative comments about your own work being reblogged, retweeted, and reposted isn't a pleasant experience.

Making the process more friendly for the designer is good for many reasons. It's kind, of course. Beyond that, it opens up the possibility of a conversation. Often the original designer of a piece has thought more about its particular problems than anyone else. We recommend bringing the designer into the conversation at every level: talking with them in advance about a public critique, giving them a chance to respond, and at every turn treating them as a competent professional.

Critics can take many steps to soften the emotional impact of redesigns on the designer.

First, if you could make a point by criticizing several different visualizations, pick whichever comes from an organization with the highest prestige. If you have to point out flaws publicly, it's better to do it to the *New York Times* than a first-year student. It's not always true that more established designers have thicker skin, but they ought to. Second, if it makes sense in the context of a critique, note the positive aspects of a design — that is, the features that need no redesign. If the color and typography are excellent and need no change, it might be a good idea to call that out.

Third, to make pedagogical points, consider a "backwards" redesign, one that takes an excellent visualization and makes it worse. In other words, take a visualization that exemplifies the point you're trying to make (say, good labeling or a good color palette) and then remove key elements (most of the labels, or change colors to vibrate against one another). This may give you the same effect as a traditional redesign, but leave the original designer flattered rather than aggrieved. It's also a good way to move past the idea that "criticism" implies a negative view of existing work.

3. Respect the critic

Criticism is hard, as hard as design. Indeed, in established media (books, movies, music) good critics are recognized as experts in their own right. As a field, we should give the same respect to our visualization critics. One occasionally hears designers complain that a critic isn't an active practitioner. Well, that may be true, but it shouldn't matter.

As a consequence, we shouldn't let some roughness in a redesign be an excuse to ignore it. A redesign doesn't need to be perfectly polished to be effective. It may even be better for it to be slightly rough. After all, a redesign isn't a competition between critic and designer, but instead a proof point for ideas about design.

A final point for designers is to keep in mind the goal of the critique process: ultimately, none of this is a personal evaluation, but instead a way for the field as a whole to improve.

Conclusion

Data visualization is still a new field. It's already become an essential medium for journalists, scientists, and anyone else who needs to understand data. But the medium is far from understood. It's early still, and there's a lot of room for improvement.

We need more criticism, and redesign is an essential part of visualization criticism. But with so much of it happening on the web — in public, instantly in view of everyone involved, available to the world without context or preparation — it can be a difficult process. In this chapter our goal has been to start a conversation about how criticism can be most productive, and cause the least stress, for those involved.

We'd like to end with a thought about the future. The redesigns and criticism we've discussed have very much been focused on technique. That's appropriate for a new medium in its growth phase. Compared to criticism of movies or books, however, it's unusual. Think of a typical book review: certainly writing style and form figure in reviews. But usually at least as much space, often much more, is given to questions of content: to character, to plot, to atmosphere. We'll know that visualization has matured as a medium when we see as much criticism about content as we do today about technique.

Acknowledgments

Following our own precepts, we've tried to make this essay part of a larger conversation. The impetus came from an online critique by Alberto Cairo, along with discussion that followed on Twitter, blogs, and email. In particular we'd like to thank Moritz Stefaner, Jan Willen Tulp, and others for helpful discussions and pointers.

Notes

[1] Visual Explanations: Images and Quantities, Evidence and Narrative.

[2] http://www.thefunctionalart.com/2014/11/redesigning-visualizations.html

[3] J. Bardzell / Interacting with Computers 23 (2011) 604–621

[4] http://en.wikipedia.org/wiki/File:2004_US_elections_map_electoral_votes.png http://commons.wikimedia.org/

wiki/File:Gastner_map_purple_byarea_bycounty.png
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