4 "What Gets Counted Counts"

Principle: Rethink Binaries and Hierarchies

Data feminism requires us to challenge the gender binary, along with other systems of counting and classification that perpetuate oppression.

"Sign in or create an account to continue." At a time in which every website seems to require its own user account, these words often elicit a groan—and the inevitability of yet another password that will soon be forgotten. But for people like Maria Munir, the British college student who famously came out as nonbinary to then president Barack Obama on live TV, the prospect of creating a new user account is more than mere annoyance.[1] Websites that require information about gender as part of their account registration process almost always only provide a binary choice: "male or female."[2] For Munir, those options are insufficient. They also take an emotional toll: "I wince as I'm forced to choose 'female' over 'male' every single time, because that's what my passport says, and ... being non-binary is still not legally recognised in the UK," Munir explains.[3]

For the millions of nonbinary people in the world—that is, people who are not *either* male *or* female, men *or* women—the seemingly simple request to "select gender" can be difficult to answer, if it can be answered at all.[4] Yet when creating an online user account, not to mention applying for a national passport, the choice between "male" or "female," and only "male" or "female," is almost always the only one.[5] These options (or the lack thereof) have consequences, as Munir clearly states: "If you refuse to register non-binary people like me with birth certificates, and exclude us in everything from creating bank accounts to signing up for mailing lists, you do not have the right to turn around and say that there are not enough of us to warrant change."[6]

"What gets counted counts," feminist geographer Joni Seager has asserted, and Munir is one person who understands that.[7] What is counted—like being a man or a woman—often becomes the basis for policymaking and resource allocation. By contrast, what is not counted—like being nonbinary—becomes invisible (although there are also good reasons for being invisible in some contexts, and we'll come back to

those shortly). Seager's research focus is gender, the environment, and policy (see figure 4.1), and she points out that there is more global data on gender being collected than ever before. And yet, these data collection efforts often still leave many people out, including nonbinary people, lesbians, and older women. Even among those who are counted, they tend to be asked very narrow questions about their lives. "Women in poor countries seem to be asked about 6 times a day what kind of contraception they use," Seager quipped in a lecture at the Boston Public Library. "But they are not asked about whether they have access to abortion. They are not asked about what sports they like to play."[8]

The process of converting qualitative experience into data can be empowering, and even has the potential to be healing, as we address toward the end of this chapter. When thoughtfully collected, quantitative data can be empowering too. So many issues of structural inequality are problems of scale, and they can seem anecdotal until they are viewed as a whole. For instance, in 2014, when film professors Shelley Cobb and Linda Ruth Williams set out to count the women involved in the film industry in the United Kingdom, they encountered a woman screenwriter who had never before considered the fact that in the United Kingdom, women screenwriters are outnumbered by screenwriters of other genders at a rate of four to one.[9] She expressed surprise: "I didn't even know that because screenwriters never get to meet each other."[10]

A similar situation occurred in the example of ProPublica's reporting on maternal mortality in the United States, as discussed in chapter 1. The investigative team set out to count all the mothers who had died in childbirth or from complications shortly thereafter. They interviewed many families of women who had died while giving birth, but, like the screenwriter, few of the families were aware that the phenomenon extended beyond their own daughters and sisters, partners and friends. This lack of data, like the issue of maternal mortality itself, is another structural problem, and it serves as an example of why feminist sociologists like Ann Oakley have long advocated for the use of quantitative methods alongside qualitative ones. Without quantitative research, Oakley explains, "it is difficult to distinguish between personal experience and collective oppression."[11]

But before collective oppression can be identified through analyses like the one that ProPublica conducted, the data must exist in the first place. Which brings us back to Maria Munir and the importance of collecting data that reflects the population it purports to represent. On this issue, Facebook was ahead of the curve when, in 2014, it expanded the gender categories available to registered users from the standard two to over fifty choices, ranging from "Genderqueer" to "Neither"—a move that was widely praised by a range of LGBTQ+ advocacy groups (figure 4.2a).[12] One year later, when the

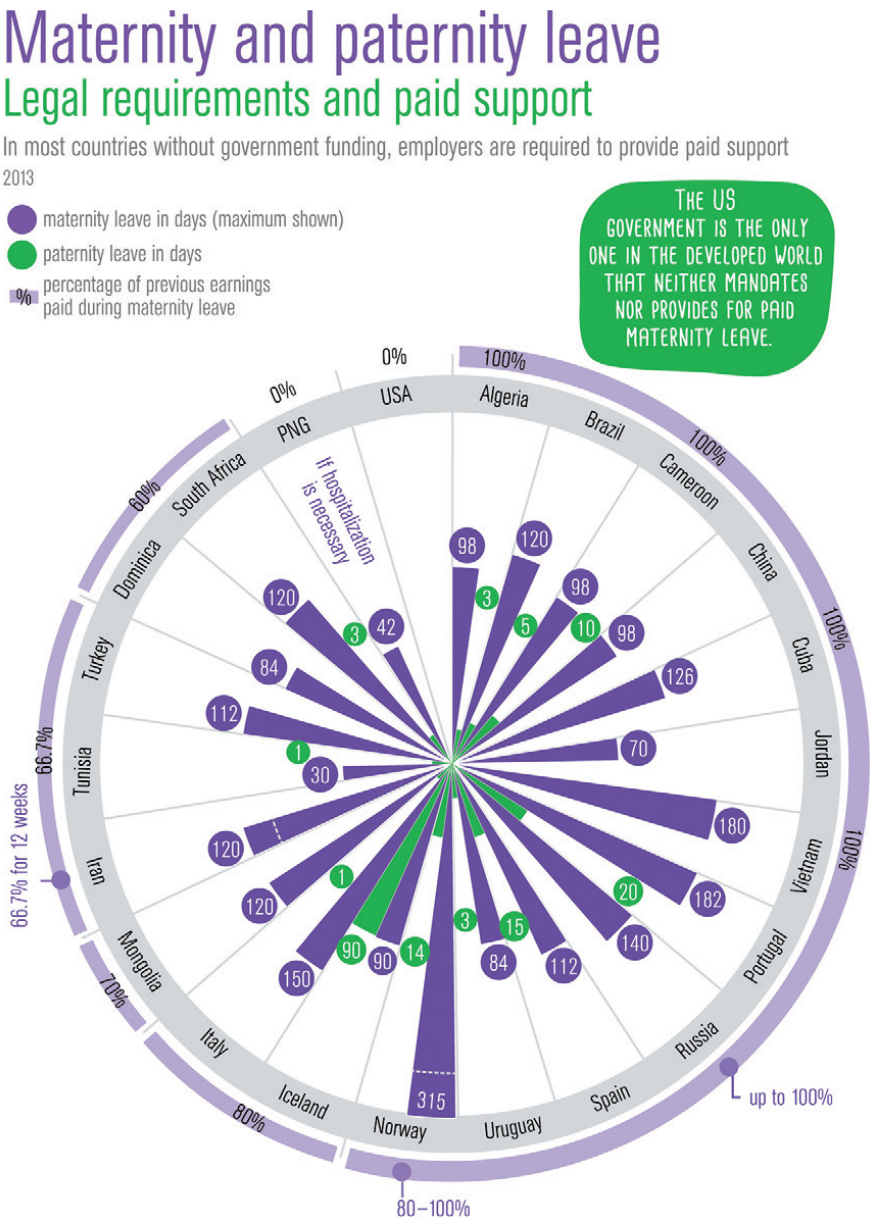


Figure 4.1
Maternity and paternity leave around the globe from *The Women's Atlas*, 5th edition (2018). Joni Seager and Annie Olson started working on the first women's atlas in 1980, when there was very little global data on women. The book is now in its fifth edition, but Seager highlights that there are still huge gender data gaps. Image courtesy of Joni Seager and Penguin Books.

company abandoned its select-from-options model altogether, replacing the "Gender" dropdown menu with a blank text field, the decision was touted as even more progressive (figure 4.2b).[13] Because Facebook users could input any word or phrase to indicate their gender, they were at last unconstrained by the assumptions imposed by any preset choice.[14]

But additional research by information studies scholar Rena Bivens has shown that below the surface, Facebook continues to resolve users' genders into a binary: either "male" or "female."[15] Evidently, this decision was made so that Facebook could allow its primary clients—advertisers—to more easily market to one gender or the other. Put another way, even if you can choose the gender that you show to your Facebook friends, you can't change the gender that Facebook provides to its paying customers (figure 4.3). And this discrepancy leads right back to the issues of power we've been discussing since the start of this book: it's corporations like Facebook, and not individuals like Maria Munir, who have the power to control the terms of data collection. This remains true even as it is people like Munir who have personally (and often painfully) run up against the limits of those classification systems—and who best know how they could be improved, remade, or in some cases, abolished altogether.

Feminists have spent a lot of time thinking about classification systems because the criteria by which people are divided into the categories of man and woman is exactly that: a classification system.[16] And while the gender binary is one of the most widespread classification systems in the world today, it is no less constructed than the Facebook advertising platform or, say, the Golden Gate Bridge. The Golden Gate Bridge is a physical structure; Facebook ads are a virtual structure; and the gender binary is a conceptual one. But all these structures were created by people: people living in a particular place, at a particular time, and who were influenced—as we all are—by the world around them.[17]

Many twentieth-century feminist scholars attempted to address the social construction of gender by treating gender as something separate from sex. But that distinction is increasingly breaking down. Both gender and sex are social constructs, as it turns out. Even sex, which today is sometimes still considered in biologically essential terms, has a distinct cultural history. It can be traced to a place (Europe) and a time (the Enlightenment) when new theories about democracy and what philosophers called "natural rights" began to emerge. Before then, there was a *hierarchy* of the sexes, with men on the top and women on the bottom. (Thanks, Aristotle![18]) But there wasn't exactly a *binary* distinction between those two (or any other) sexes. In fact, according to historian of sex and gender Thomas Laqueur, most people believed that women were just inferior men, with penises located inside instead of outside of their bodies and that—for reals!—could descend at any time in life.[19]

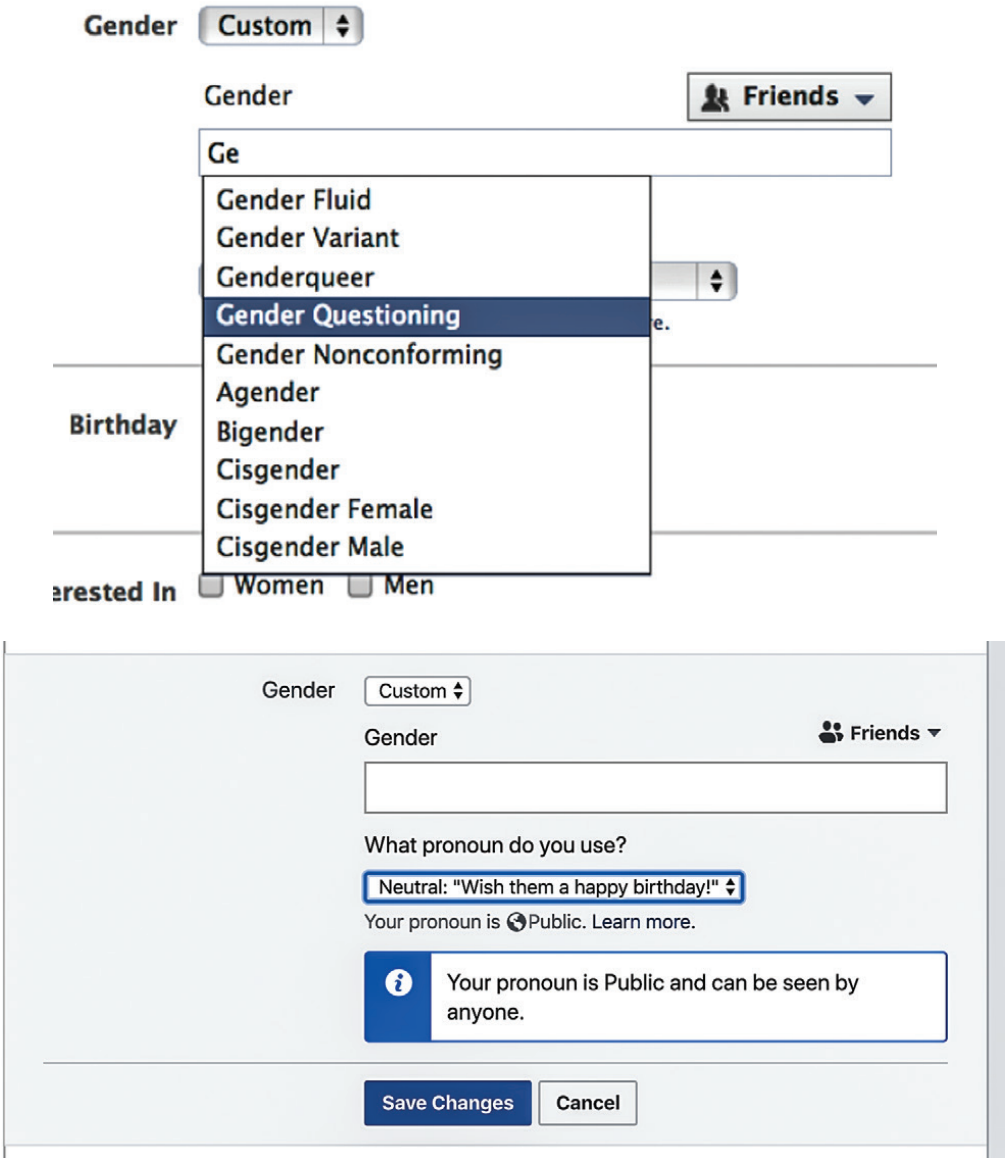


Figure 4.2
(a) Facebook's initial attempt to allow users to indicate additional genders, circa 2014. Image courtesy of *Slate*. (b) Facebook's updated gender field, circa 2018. Screenshot by Lauren F. Klein.

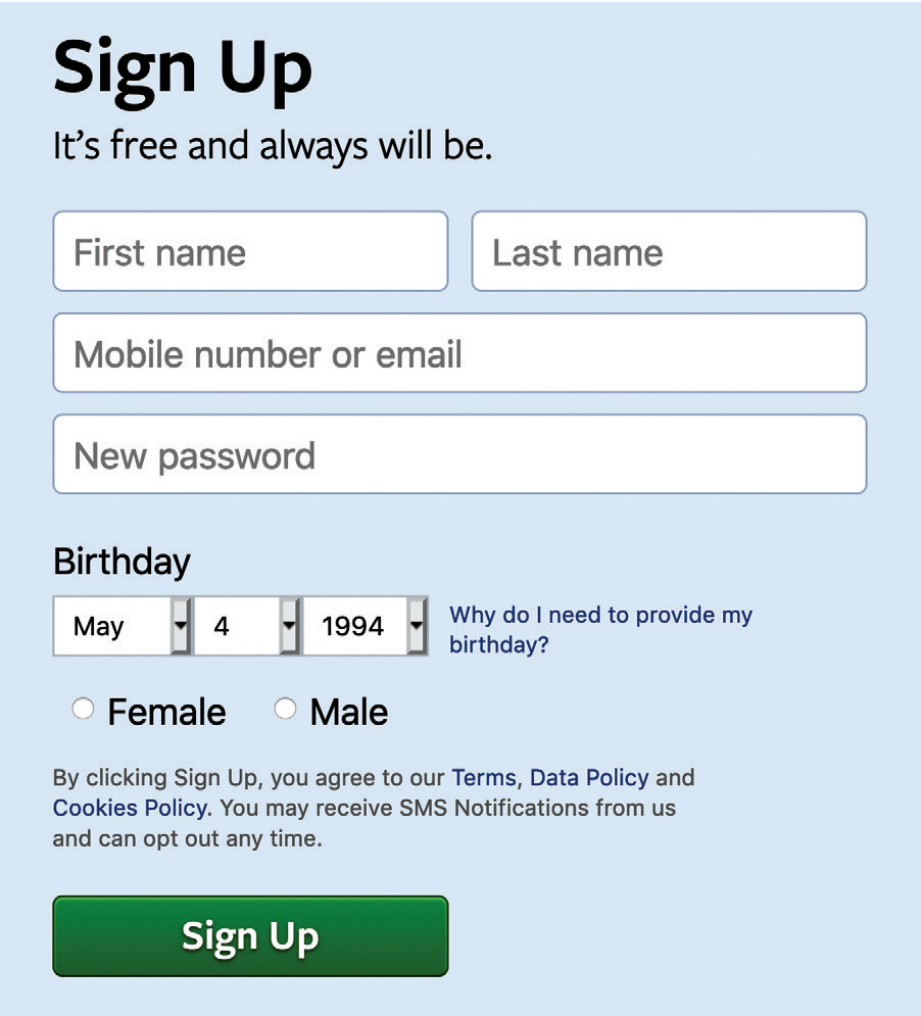


Figure 4.3
Detailed view of Facebook's new account creation page, circa 2018. Note that you still have to choose "Female" or "Male"—a binary choice—when you sign up. Screenshot by Lauren F. Klein.

For the idea of a sex binary to gain force, it would take figures like Thomas Jefferson declaring that all men were created equal, and entire countries like the United States to be founded on that principle. Once that happened, political leaders began to worry about what, exactly, they had declared: to whom did the principle of equality apply? All sorts of systems for classifying people have their roots in that era—not only sex but also, crucially, race.[20] Before the eighteenth century, Western societies understood race as a concept tied to religious affiliation, geographic origin, or some combination of

both. Race had very little to do with skin color until the rise of the transatlantic slave trade, in the seventeenth century.[21] And even then, race was still a hazy concept. It would take the scientific racism of the mid-eighteenth century for race to begin to be defined by Western societies in terms of black and white.

Take Carl Linnaeus, for example, and the revolutionary classification system that he is credited with creating.[22] Linnaeus's system of binomial classification is the one that scientists still use to today to classify humans and all other living things. But Linnaeus's system didn't just include the category of *homo sapiens*, as it turns out. It also incorrectly—but as historians would tell you, unsurprisingly—included five subcategories of humans separated by race. (One of these five was set aside for mythological humans who didn't exist in real life, in case you're still ready to get behind his science.) But Linnaeus's classification system wasn't even the worst of the lot. Over the course of the eighteenth century, increasingly racist systems of classification began to emerge, along with pseudosciences like comparative anatomy and physiognomy. These allowed elite white men to provide a purportedly scientific basis for the differential treatment of people of color, women, disabled people, and gay people, among other groups. Although those fields have long since been discredited, their legacy is still visible in instances as far-ranging as the maternal health outcomes that we've already discussed, to the divergent rates of car insurance that are offered to Black vs. white drivers, as described in an investigation conducted by ProPublica and Consumer Reports.[23] What's more, as machine learning techniques are increasingly extended into new domains of human life, scientific racism is itself returning. Pointing to and debunking one machine learning technique that employs images of faces in an attempt to classify criminals, three prominent artificial intelligence researchers—Blaise Agüera y Arcas, Margaret Mitchell, and Alexander Todorov—have asserted that scientific racism has "entered a new era."[24]

A simple solution might be to say, "Fine, then. Let's just not classify anything or anyone!" But the flaw in that plan is that data must be classified in some way to be put to use. In fact, by the time that information becomes data, it's already been classified in some way. Data, after all, is information made *tractable*, to borrow a term from computer science. "What distinguishes data from other forms of information is that it can be processed by a computer, or by computer-like operations," as Lauren has written in an essay coauthored with information studies scholar Miriam Posner.[25] And to enable those operations, which range from counting to sorting and from modeling to visualizing, the data must be placed into some kind of category—if not always into a conceptual category like gender, then at the least into a computational category like *Boolean* (a type of data with only two values, like true or false), *integer* (a type of

number with no decimal points, like 237 or –1), or *string* (a sequence of letters or words, like "this").

Classification systems are essential to any working infrastructure, as information theorists Geoffrey Bowker and Susan Leigh Star have argued in their influential book *Sorting Things Out*.[26] This is true not only for computational infrastructures and conceptual ones, but also for physical infrastructures like the checkout line at the grocery store. Think about how angry a shopper can get when they're stuck in the express line behind someone with more than the designated fifteen items or less. Or, closer to home, think of the system you use (or should use) to sort your clothes for the wash. It's not that we should reject these classification systems out of hand, or even that we could if we wanted to. (We're pretty sure that no one wants all their socks to turn pink.) It's just that once a system is in place, it becomes naturalized as "the way things are." This means we don't question how our classification systems are constructed, what values or judgments might be encoded into them, or why they were thought up in the first place. In fact—and this is another point made by Bowker and Star—we often forget to ask these questions until our systems become objects of contention, or completely break down.

Bowker and Star give the example of the public debates that took place in the 1990s around the categories of race employed on the US Federal Census. At issue was whether people should be able to choose multiple races on the census form. Multiracial people and their families were some of the main proponents of the option, who saw it as a way to recognize their multiple identities rather than forcing them to squeeze themselves into a single, inadequate box. Those opposed included the Congressional Black Caucus as well as some Black and Latinx civil rights groups that saw the option as potentially reducing their representative voice.[27] Ultimately, the 2000 census did allow people to choose multiple races, and millions of people took advantage of it. But the debates around that single category illustrate how classification gets complicated quickly, and with a range of personal and political stakes.[28]

Classification systems also carry significant material consequences, and the US Census provides an additional example of that. Census counts are used to draw voting districts, make policy decisions, and allocate billions of dollars in federal resources. The recent Republican-led proposal to introduce a question about citizenship status on the 2020 census represents an attempt to wield this power to very pointed political ends. Because undocumented immigrants know the risks, like deportation, that come with being counted, they are less likely to complete the census questionnaire. But because both political representation and federal funding are allocated according to the number and geographic areas of people counted in the census, undercounting

undocumented immigrants (and the documented immigrants they often live with) means less voting power—and fewer resources—accorded to those groups. This is a clear example of what we term the *paradox of exposure*: the double bind that places those who stand to significantly gain from being counted in the most danger from that same counting (or classifying) act.

In each of these cases, as is true of any case of not fitting (or not wanting to fit) neatly into a box, it's important to ask whether it's the categories that are inadequate, or whether—and this is a key feminist move—it's the system of classification itself. Lurking under the surface of so many classification systems are false binaries and implied hierarchies, such as the artificial distinctions between men and women, reason and emotion, nature and culture, and body and world. Decades of feminist thinking have taught us to question why these distinctions have come about; what social, cultural, or political values they reflect; what hidden (or not so hidden) hierarchies they encode; and, crucially, whether they should exist in the first place.

Questioning Classification Systems

Let's spend some time with an actual person who has started to question the classification systems that surround him: one Michael Hicks, an eight-year-old Cub Scout from New Jersey. Why is Mikey, as he's more commonly known, so concerned about classification? Well, Mikey shares his name with someone who has been placed on a terrorist watch list by the US federal government. As a result, Mikey has also been classified as a potential terrorist and is subjected to the highest level of airport security screening every time that he travels. "A terrorist can blow his underwear up and they don't catch him. But my 8-year-old can't walk through security without being frisked," his mother lamented to Lizette Alvarez, a reporter for the *New York Times* who covered the issue in 2010.[29]

Of course, in some ways, Mikey is lucky. He is white, so he does not run the risk of racial profiling—unlike, for example, the many Black women who receive TSA pat-downs due to their natural hair.[30] Moreover, Mikey's name sounds Anglo-European, so he does not need to worry about religious or ethnic profiling either—unlike, for another example, people named Muhammad who are disproportionately pulled over by the police due to their Muslim name.[31] But Mikey the Cub Scout still helps to expose the brokenness of some of the categories that structure the TSA's terrorist classification system; the combination of first and last name is simply insufficient to classify someone as a terrorist or not.

Or, consider another person with a history of bad experiences at the (literal) hands of the TSA. Sasha Costanza-Chock is nonbinary, like Maria Munir. They are also a design professor at MIT, so they have a lot of experience both living with and thinking through oppressive classification systems. In a 2018 essay, "Design Justice, A.I., and Escape from the Matrix of Domination," they give a concrete example of why design justice is needed in relation to data.[32] The essay describes how the seemingly simple system employed by the operators of those hands-in-the-air millimeter-wave airport security scanning machines is in fact quite complex—and also fundamentally flawed.

Few cisgender people are aware of the fact that before you step into a scanning machine, the TSA agent operating the machine looks you up and down, decides whether you are a man or a woman, and then pushes a button to select the corresponding gender on the scanner's touchscreen interface. That human decision loads the algorithmic profile for either male bodies or female ones, against which your body's measurements are compared. If your measurements diverge from the statistical norm of that gender's body—whether the discrepancy is because you're concealing a deadly weapon, because your body doesn't fit neatly into either of the two categories that the system has provided, or because the TSA agent simply made the wrong choice—you trigger a "risk alert." Then, in an act of what legal theorist Dean Spade terms *administrative violence*, you are subjected to the same full-body pat-down as a potential terrorist.[33] Here it's not that the scanning machines rely upon an insufficient number of categories, as in the case of Mikey the Cub Scout, or that they employ the wrong ones, as Mikey's mom would likely say. It's that the TSA scanners shouldn't rely on gender to classify air travelers to begin with. (And while we're going down that path, how about we imagine a future without a state agency that systematically pathologizes Black women and trans people and Cub Scouts in the first place?)

So when we say that what gets counted counts, it's folks like Sasha Costanza-Chock or Mikey Hicks or Maria Munir that we're thinking about. Because flawed classification systems—like the one that underlies the airport scanner's risk-detection algorithm or the one that determines which names end up on terrorist watch lists or simply (simply!) the gender binary—are not only significant problems in themselves, but also symptoms of a more global condition of inequality. The matrix of domination, which we introduced in chapter 1, describes how race, gender, and class (among other things) intersect to enhance opportunities for some people and constrain opportunities for others.[34] Under the matrix of domination, normative bodies pass through scanners, borders, and bathrooms with ease; these systems have been designed by people like them, for people like them, with an aim—sometimes explicit—of keeping people not like them out.[35]

As these examples help to show, the forces that operate through the matrix of domination are sneaky and diffuse. And they show up everywhere—even in pockets on pants. A recent journalistic investigation of the size of pockets in eighty pairs of men's and women's jeans confirmed what women (and men and nonbinary people who wear women's jeans) have been saying anecdotally for years: that their pants pockets just aren't big enough (figure 4.4).[36] More specifically, the pockets of jeans designed for women are 48 percent shorter and 6.5 percent narrower than the pockets of jeans designed for men. This size does matter! According to the same study, only 40 percent

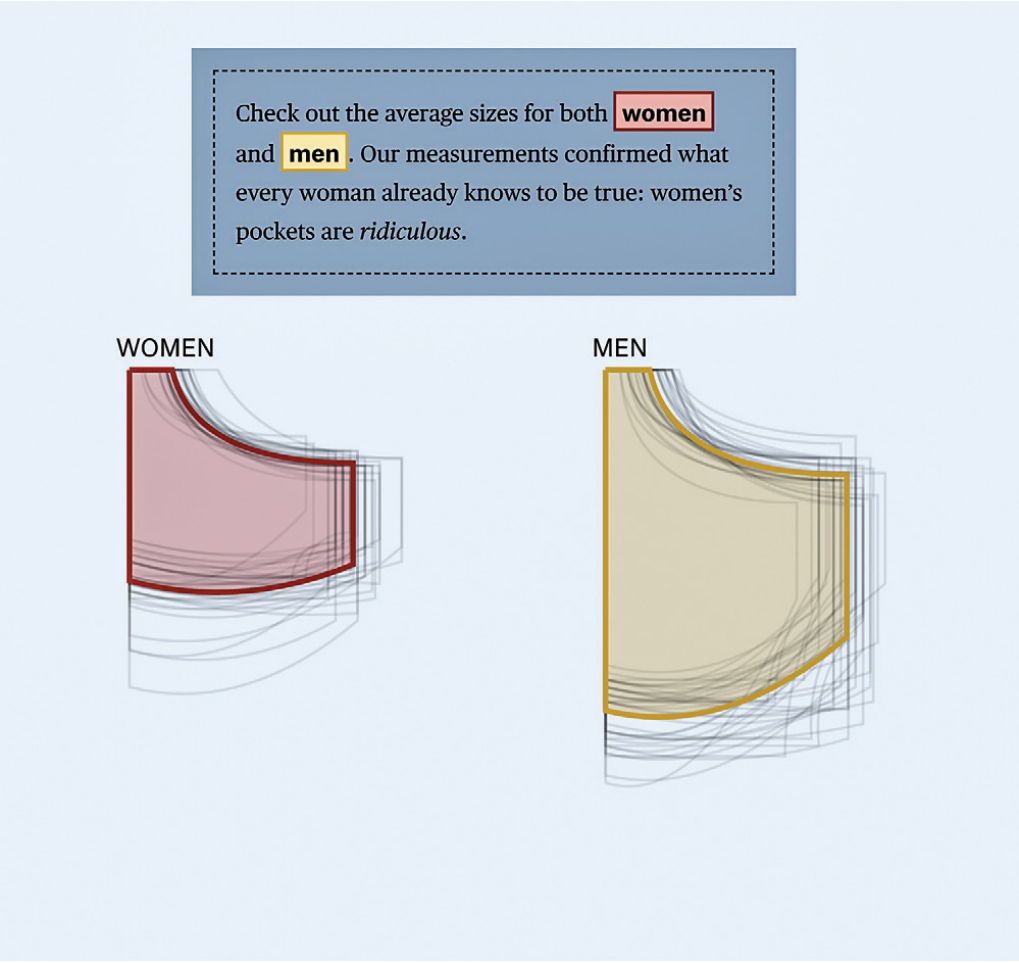


Figure 4.4
From "Someone Clever Once Said Women Were Not Allowed Pockets," a comparative study of pockets in women's and men's jeans by The Pudding (2018). Visualization by Jan Diehm and Amber Thomas for The Pudding.

of the front pockets of women's jeans can fit a smartphone, and less than half "can fit a wallet *specifically* designed to fit in front pockets." Hence the thriving market for women's handbags (to hold the aforementioned front-pocket wallet) and for replacement smartphone screens (for when your phone invariably falls out of your too-small pocket and cracks).

Now, the designers of any particular pair of women's jeans are almost certainly not thinking: "Let's oppress women by making their pockets too small." They are probably only thinking about what looks nice. But what looks nice has a history too. Before the seventeenth century, "pockets" were external sacks on strings that could be tied above or below other garments. But starting in the 1600s, men's clothing began to feature internal pockets. Meanwhile, women's clothing became increasingly close-cut. By the late eighteenth century, the women's pocket reached its breaking point, resulting in emergence of a new fashion item called a reticule, otherwise known as a purse. These tiny handbags were made out of cloth and, according to the Victoria and Albert Museum's helpful online history of pockets, could not hold very much.[37] And yet, as the museum curators point out, in an era in which most people shared all of their shelves and dressers, these reticules were one of the few places for women to store any items they wanted to keep to themselves. Fast forward to the present, and women (and people who wear women's fashion) must still carry their belongings outside of their clothes and on public display. They're also limited in their ability to use both of their hands at the same time. It's (mostly) a minor annoyance, but it's one way among many that the *patriarchy*—a term that describes the combination of legal frameworks, social structures, and cultural values that contribute to the continued male domination of society—inadvertently and invisibly reproduces itself. In this case, it's pants—perhaps even the ones you're wearing right now—that compound and consolidate the patriarchy's oppressive force.

In addition to pants pockets, one of the other things that upholds the patriarchy is, as it turns out, our ideas about gender itself. We've already asserted that *gender is a social construct*, but what does this phrase really mean? Queer theorist Judith Butler has long maintained that gender is best understood as a repeated performance, a set of categories that cohere by, for instance, wearing jeans with small pockets (or no pockets at all) or by participating in an activity that is similarly gender-coded, like child-rearing, or—importantly for Butler—having heterosexual sex.[38] These *performative acts*, as she terms them, repeated so many times that they become taken as fact, are what define the gender categories that we have today. Butler's idea of gender as performative moves away from an essentialist conception of the term: the idea that there is some innate or "essential" criteria that makes one, for instance, a woman or man. But these

performances still reinforce the *categories* of gender, she reminds us, even if the actions and activities that determine them are not innate.

Gender is certainly complicated. This is one thing about which most contemporary scholars of gender largely agree. Conceptions of gender in health and clinical fields are also evolving as well. For example, the American Medical Association now calls gender a "spectrum" rather than a binary, and as of 2018 it issued a firm statement that "sex and gender are more complex than previously assumed."[39] But it's important to remember that there have always been more variations in gender identity and expression than most Anglo-Western societies have cared to acknowledge or to collectively remember. This is evidenced in the range of regional and vernacular terms, such as *kothi*, *hijra*, and *dhurani*, that are currently used to describe the genders of people across South Asia that fall outside the binary; we see it in the additional umbrella terms, such as *two-spirit*, that describe people in some North American Indigenous communities; and many more.[40] Not to mention that some people are gender-fluid, meaning their gender identity may shift from day to day, year to year, or situation to situation. And yet—at least in a US context—gender data is still almost always collected in the binary categories of "male" and "female" and visually represented by some form of binary division as well.[41] This remains true even as a 2018 Stanford study found that, when given the choice among seven points on a gender spectrum, more than two-thirds of the subjects polled placed themselves somewhere in the middle.[42]

As survey designers, and data scientists more generally, there would seem to be an obvious response to the Stanford report: collect gender data in more than binary categories, making sure to disaggregate the data—that is, compare the data by genders during the analysis phase. One recent alternative to the binary, developed by Public Health England in collaboration with LGBTQ+ organizations in the United Kingdom, is in evidence in figure 4.5. This two-item questionnaire was designed for use in routine national surveillance of HIV in England and Wales to determine self-identified gender and cis or trans status in a public health context. The designers offer three named genders, a catch-all fourth category, and an option for not disclosing gender identity. In a separate question, they ask about gender at birth, again giving an option for not disclosing. The survey design uses sensitive wording and inclusive terminology to allow trans and genderqueer populations to be counted. These questions are being considered for expanded use across other national health records and data collection systems in the United Kingdom.

Should all future gender data collection use this model? Not necessarily, and here's why: In a world in which quantification always leads to accurate representation, and accurate representation always leads to positive change, then always counting gender

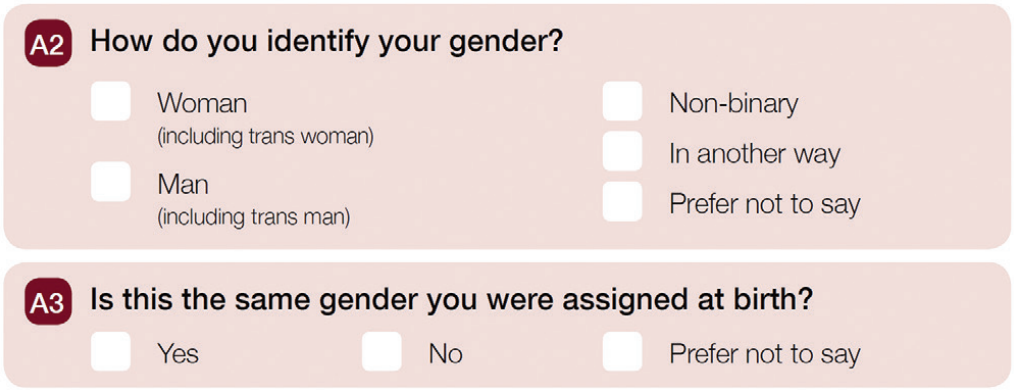


Figure 4.5
From the Positive Voices survey of people living with HIV in England and Wales developed by Public Health England in collaboration with several partner organizations. This represents current best practices for collecting nonbinary gender data in an Anglo-Western public health context, but it's still important to recognize that different decisions might be warranted depending on the context. Courtesy of Peter Kirwin, Public Health England, 2018.

identities outside the binary makes perfect sense. But being represented also means being made visible, and being made visible to the matrix of domination—which continuously develops laws, practices, and cultural norms to police the gender binary—poses significant risks to the health and safety of minoritized groups. Under the current administration in the United States, for example, transgender people are banned from serving in the military and, once identified as such, denied access to certain forms of healthcare.[43] This demonstrates some of the risks of having one's gender counted as something other than man or woman—risks that can occur in many contexts, depending on what data are being collected, by whom, and whether they are personally identifiable (or easily deanonymized). It's also important to recognize how trans and nonbinary people may possibly be identified even within otherwise large datasets simply because there are fewer of them relative to the larger population. This possibility poses additional risks, in the form of unwanted attention in the case of people who would prefer not to disclose their gender identity, or in the form of discrimination, violence, or even imprisonment, depending on the place they live.

As data scientists, what should we do amid these potential harms? Depending on the circumstances and the institution that is doing the collecting, the most ethical decision can vary. It might be to avoid collecting data on whether someone is cis or transgender, to make all gender data optional, to not collect gender data at all, or even

to stick with binary gender categories. Social computation researcher Oliver Haimson has asserted that "in most non-health research, it's often not necessary to know participants' assigned gender at birth."[44] Heath Fogg Davis agrees: his book *Beyond Trans* argues that we don't need to classify people by sex on passports and licenses, for bathrooms or sports, among other things.[45] By contrast, J. Nathan Matias, Sarah Szalavitz, and Ethan Zuckerman chose to keep gender data in binary form for their application FollowBias, which detects gender from names, in order to avoid making a person's gender identity public against their wishes.[46]

The ethical complexity of whether to count gender, when to count gender, and how to count gender illuminates the complexity of acts of classification against the backdrop of structural oppression. Because when it comes to data collection, and the categories that structure it, there are power imbalances up and down, side to side, and everywhere in between. Because of these asymmetries, data scientists must proceed with awareness of context (discussed further in chapter 6) and an analysis of power in the collection environment (discussed further in chapter 1) to determine whose interests are being served by being counted, and who runs the risk of being harmed.

Rethinking Binaries in Data Visualization

A feminist critique of counting, and of the binary classification systems that often structure those acts, is not limited to a focus on gender alone. A binary logic also pervades our thinking about race, for example, as feminist scholars Brittney Cooper and Margaret Rhee explain. Drawing from ideas about intersectionality, they call for "hacking" the Black/white binary that, on the one hand, helps to expose the racism experienced by Black people in the United States and, on the other, erases the other forms of racism experienced by Indigenous as well as Latinx, Asian American, and other minoritized groups. "Binary racial discourses elide our struggles for justice," they state plainly.[47] By challenging the binary thinking that erases the experiences of certain groups while elevating others, we can work toward more just and equitable data practices and consequently toward a more just and equitable future.

Sometimes, however, the goal of challenging binary thinking can be constrained by the realities of the field. Visualization designers, for example, do not typically have control over the collection practices of the data they are asked to visualize. They often inherit binary data that they then need to "hack" from within. What might this look like? We might point to the reporters on the Lifestyle Desk of the *Telegraph*, a British newspaper, who, in March 2018, were considering how to honor International Women's Day and were struck by the significant gender gap in the United Kingdom in terms

of education, politics, business, and culture.[48] As journalists, they were working with multiple sources of data collected by other agencies, which all came in binary form. But they wanted to ensure that they didn't further reinforce any gender stereotypes. They paid particular attention to color. One line of designer logic would favor cultural convention for interpretability, like using pink for women and blue for men, but a feminist line would use color choices to hack those same conventions (figure 4.6).

Pink and blue is, after all, another hierarchy, and the goal of the *Telegraph* team members was to mitigate inequality, not reinforce it. So they took a different source for inspiration: the Votes for Women campaign of early twentieth-century England, in which purple was employed to represent freedom and dignity and green to represent

Figure 4.6
"Born Equal. Treated Unequally" was an interactive feature in the *Telegraph* in 2018 that examined the gender gap in the United Kingdom along a number of dimensions. Although the authors treated gender as a binary category, they used color to challenge stereotypically man/woman color coding. Feature by Claire Cohen, Patrick Scott, Ellie Kempster, Richard Moynihan, Oliver Edgington, Dario Verrengia, Fraser Lyness, George Ioakeimidis, and Jamie Johnson, for the *Telegraph*.

hope. When thinking about which of these colors to assign to each gender, they took a perceptual design principle as their guide: "Against white, purple registers with far greater contrast and so should attract more attention when putting alongside the green [sic], not by much but just enough to tip the scales. In a lot of the visualisations men largely outnumber women, so it was a fairly simple method of bringing them back into focus," Fraser Lyness, the *Telegraph*'s director of graphic journalism told visualization designer Lisa Charlotte Rost.[49] Here, one hierarchy—the hierarchy in which colors are perceived by the eye—was employed to challenge another one: the hierarchy of gender. When put into practice, this simple method had the result of communicating clearly without reinforcing stereotypes.

But the *Telegraph* journalists could have gone one step further to rethink binaries. They had an opportunity to communicate to the public that gender is not a binary by spelling that out—in the text of the story or in a caption under the graphics or by showing visually that there was no data for nonbinary people. Their colleagues at the *Guardian* recently adopted this latter strategy in their interactive piece "Does the New Congress Reflect You?" about the 2018 US midterm elections.[50] The piece presents three categories: cis male, cis female, and trans + nonbinary. When you click on "trans + nonbinary," as in figure 4.7, the interactive map displays all of the districts in grey, because "0 people in Congress are like you." The absence of data becomes an important takeaway, as meaningful as the data themselves.[51]

These examples have shown gender as a dimension of analysis, but how might we visually represent gender itself? This is a challenge of visualizing complexity of the highest degree, and Amanda Montañez, a designer for *Scientific American*, took this challenge head on (figure 4.8). She was tasked with creating an infographic to accompany an article on the evolving science of gender and sex—categories that she, like most people, viewed as distinct but related.[52] As she explains in a blog post on the *Scientific American* website, she first envisioned a simple spectrum, or perhaps two spectrums: one for sex and one for gender.[53] But she soon found confirmation of what we've been saying so far in this chapter: that few things in life can be truly reduced to binaries, and that insisting on binary categories of data collection—with respect to gender, to sex, to their relation, or to anything else—fails to acknowledge the value of what (or who) rests in between and outside.

We have already established that gender is more than binary; but it's less commonly acknowledged that sex is more than a binary too. As feminist biologist Anne Fausto-Sterling confirms, "There is no single biological measure that unassailably places each and every human into one of two categories—male or female."[54] Intersex people, who constitute an estimated 1.7 percent of the population, may have ovaries and a penis,

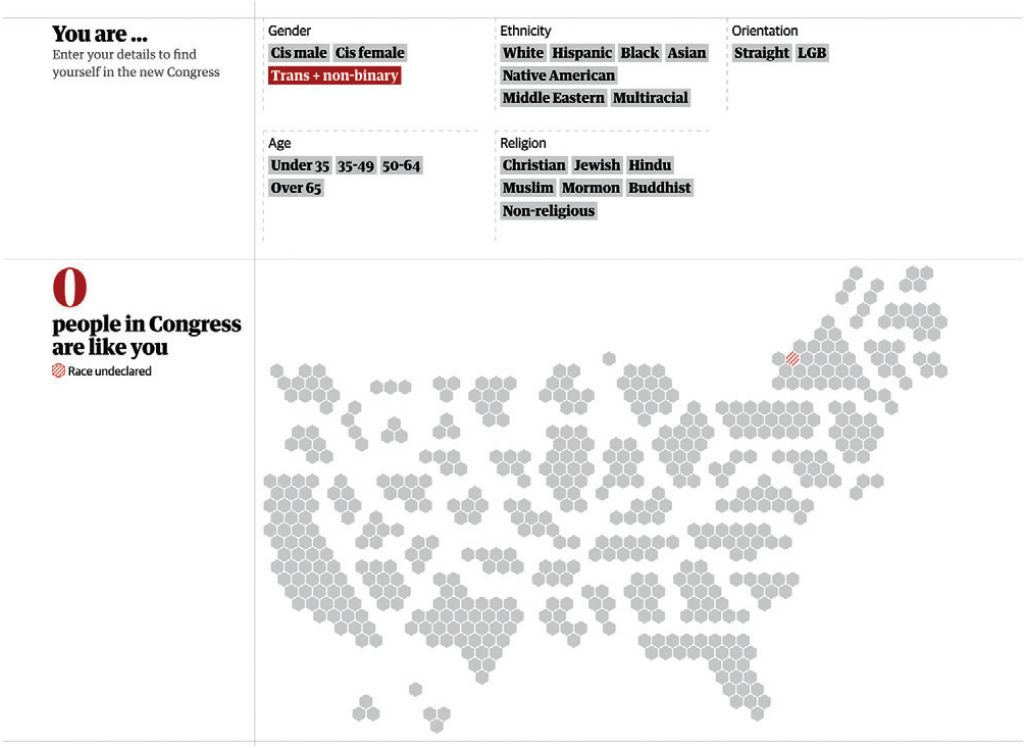


Figure 4.7
"Does the New Congress Reflect You?" is a 2018 interactive that appeared in the *Guardian*. Users select their own demographic characteristics to see how many people like them are in the 2018 Congress. Clicking on "trans + nonbinary" leads to a blank map showing zero people in Congress like you. Image by Sam Morris, Juweek Adolphe, and Erum Salam for the *Guardian*.

or "mosaic genetics" in which some of one's cells have XX chromosomes and some have XY.[55] It's also increasingly acknowledged that that sex, like gender, and sometimes together with gender, is multilayered and continuously unfolding throughout a person's life.

To begin to represent this complexity, Montañez had to begin by rejecting much of the data and research that she and her research assistant turned up, either on account of flawed categories or on account of flawed collection practices. She decided to focus on sex, and after an extensive design process, which included consulting with domain experts, Montañez and the design firm Pitch Interactive, which helped finalize the diagram, arrived at the result. *Beyond XX and XY* is a complex diagram, which employs a color spectrum to represent the sex spectrum, a vertical axis to represent change over

time, and branching arrows to connect to text blocks that provide additional contextual information. The design offers a beautifully executed visual challenge to the scientifically incorrect idea that there are only two sexes, and even that the concepts of sex and gender are wholly distinct. Visualization is often thought of as a way to reduce complexity, but here it operates in the reverse—to push simple, oppressive ideas to be more complex, nuanced, and just.

Refusing Data, Recovering Data

Montañez's graphic made what was already counted count. In other words, she took what scientists and theorists knew to be true about the nature of sexual differentiation and made that knowledge more accessible and public. But counting in itself is not necessarily an unmitigated good, nor is putting it on public display. We have already introduced the idea of the paradox of exposure where people are harmed by being made visible to a system. But because system designers from dominant groups do not experience the harms of being counted or of being made visible without consent—this is the privilege hazard, once again—they rarely anticipate these needs or account for them in the design process. This is the reason that questions about counting must be accompanied by questions about consent, as well as of personal safety, cultural dignity, and historical context.

It's Facebook, once again, that helps to prove this point. Information studies scholars Oliver Haimson and Anna Lauren Hoffman have studied the effects of the company's "real name" policy, under which the platform determines each user's registered name to be either "real" and authentic or simply "fake."[56] (In our teacher voices, we now say: Does anyone note the problem with this binary thinking here?) Haimson and Hoffman point out that trans and queer people may choose to have multiple online identities, which may be fluid and contextual and possibly necessary to protect themselves. As another example, abuse survivors may need to take steps to make themselves unfindable through search, even as they still want to be connected to their loved ones.

Figure 4.8 (following two pages)
Beyond XX and XY (2017) visualizes the known factors that contribute to sexual differentiation at different stages of human life, from conception to birth to puberty and beyond. Contrary to received wisdom, sex is not a binary that is fixed at birth, but rather a layered and time-based process of differentiation, with more than two possible outcomes. Reproduced with permission. Copyright © 2017 *Scientific American*, a division of Nature America, Inc. All rights reserved.

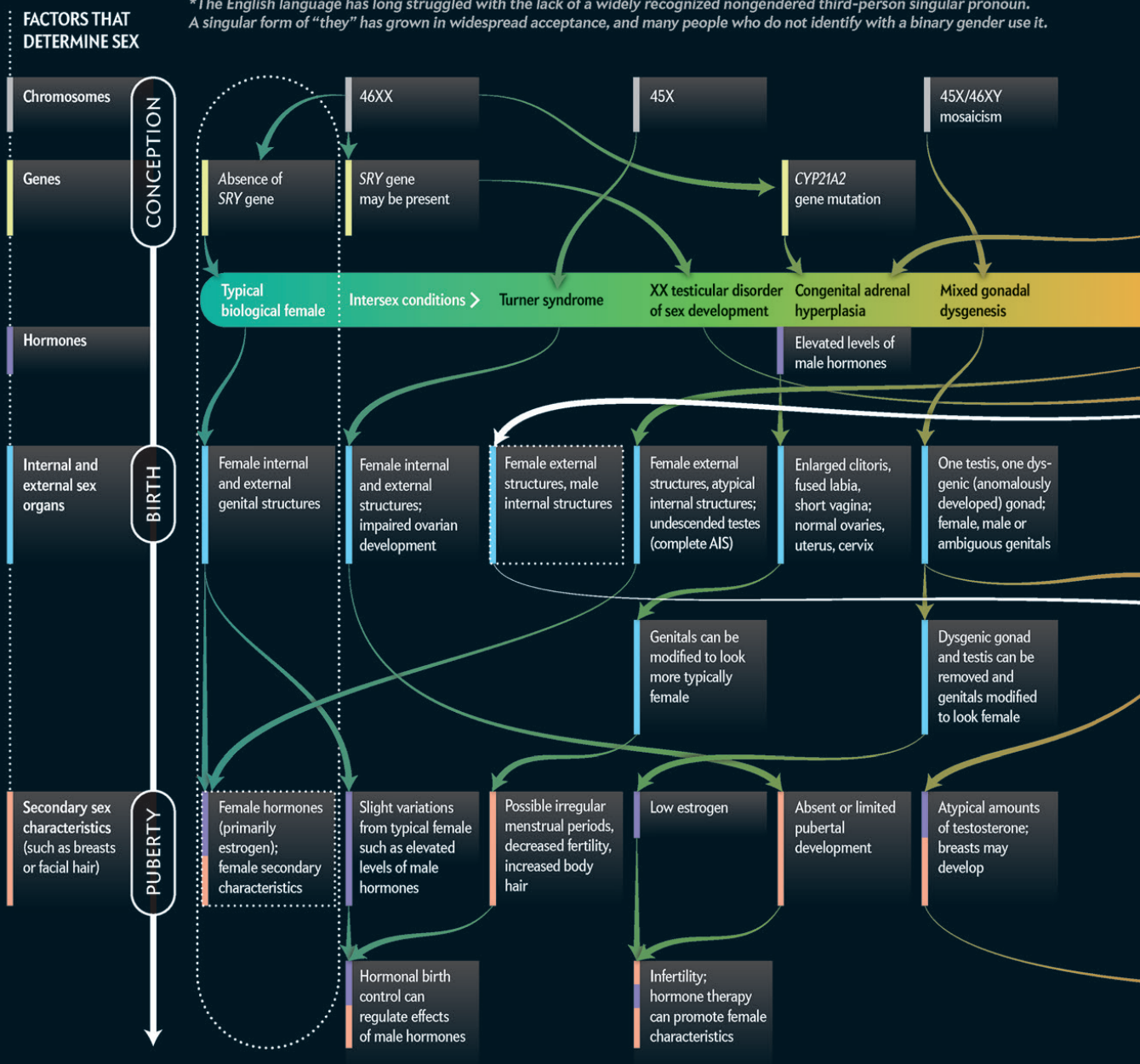
BEYOND XX AND XY

A host of factors figure into whether someone is female, male or somewhere in between

Humans are socially conditioned to view sex and gender as binary attributes. From the moment we are born—or even before—we are definitively labeled "boy" or "girl." Yet science points to a much more ambiguous reality. Determination of biological sex is staggeringly complex, involving not only anatomy but an intricate choreography of genetic and chemical factors that unfolds over time. Intersex individuals—those for whom sexual development follows an atypical trajectory—are characterized by a diverse range of conditions, such as 5-alpha reductase deficiency (*circled*). A small cross section of these conditions and the pathways they follow is shown here. In an additional layer of complexity, the gender with which a person identifies does not always align with the sex they* are assigned at birth, and they may not be wholly male or female. The more we learn about sex and gender, the more these attributes appear to exist on a spectrum.

—*Amanda Montañez*

**The English language has long struggled with the lack of a widely recognized nongendered third-person singular pronoun. A singular form of "they" has grown in widespread acceptance, and many people who do not identify with a binary gender use it.*



Graphic by Pitch Interactive and Amanda Montañez

The Gender Spectrum

A transgender woman is a person who was assigned male at birth based on her anatomy but who identifies as a woman.

A cisgender woman is a person who was assigned female at birth based on her anatomy and who also identifies as a woman.

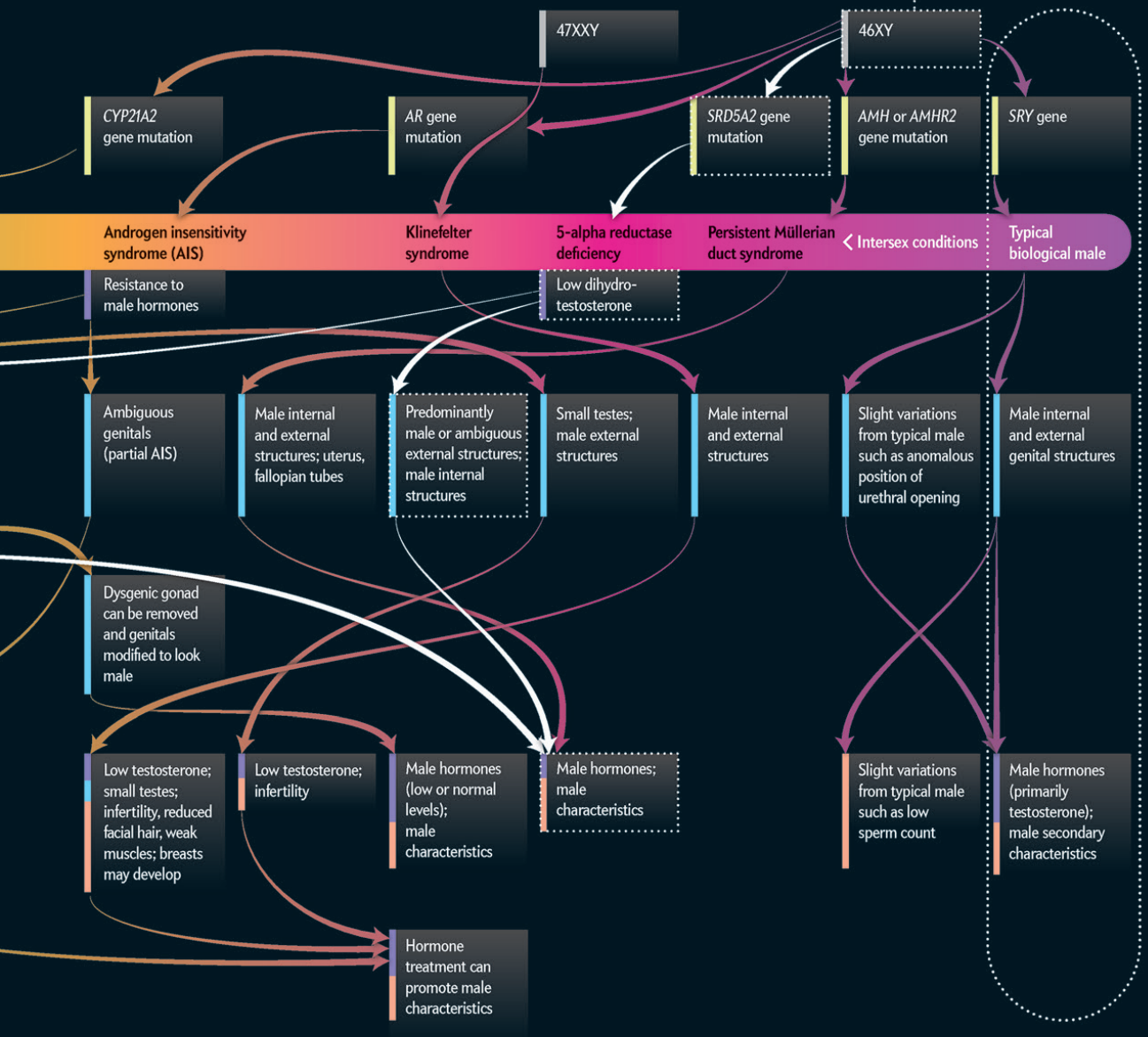
A nonbinary person is someone who identifies as neither completely female nor completely male. Such an individual may identify with both genders or neither gender, or they may be gender fluid, meaning their gender fluctuates between female and male.

A transgender man is a person who was assigned female at birth based on his anatomy but who identifies as a man.

A cisgender man is a person who was assigned male at birth based on his anatomy and who also identifies as a man.

Sexuality refers to an individual's sexual orientation or to the kind of person to whom they are attracted. Sexuality is also a spectrum but is separate from both sex and gender.

5-alpha reductase deficiency is an intersex condition that can follow multiple pathways throughout development. Affected individuals have a chromosomal makeup of 46XY, like a typical biological male, but a genetic mutation causes a deficiency of the hormone dihydrotestosterone. Patients' external anatomy can vary, so an individual might be assigned to either sex at birth, but at puberty a surge of testosterone promotes male characteristics. As a result, patients who are raised as girls often end up identifying as male.



SOURCE: RESEARCH BY AMANDA HOBBS; EXPERT REVIEW BY AMY WISNIEWSKI *University of Oklahoma Health Sciences Center*

Compounding the contextual nature of these factors, Facebook enforces its real name policy algorithmically—flagging names with "too many" words or with unusual capital letters. Haimson and Hoffman note that Facebook's algorithms disproportionately flag Native American names for violation because those names often differ in structure and form from Anglo-Western names (the subject position of the systems' designers, and therefore presumed to be the default; the privilege hazard once again). What's more, users can also report other users for not having real names, resulting in—for example—a single person systematically targeting several hundred drag queens' profiles for removal. Facebook claims that the real name policy exists for safety, but Haimson and Hoffman clearly show that the policy actively imperils the safety of some of the platform's most marginalized users. As we've already begun to suggest, sometimes the most ethical thing to do is to help people be obscure, hidden, and invisible.[57] The example of Facebook demonstrates the fundamental importance of obtaining consent when counting and of enabling individuals to refuse acts of counting and classification in light of potential harms.

Acts of counting and classification, especially as they relate to minoritized groups, must always balance harms and benefits. When data are collected about real people and their lives, risks ranging from exposure to violence are always present. But when deliberately considered, and when consent is obtained, counting can contribute to efforts to increase valuable and desired visibility. The Colored Conventions Project (CCP), led by a team of students and faculty at the University of Delaware, demonstrates how to thoughtfully navigate this balance in the present by looking at the past.[58] Among the goals of the project is to create a machine-readable corpus of meeting minutes from the nineteenth-century Colored Conventions: events in which Black Americans, fugitive and free, gathered to strategize about how to achieve legal, social, economic, and educational justice. These meeting minutes are valuable because they have yet to be counted, so to speak, in the stories commonly told about the movement to end slavery in the nineteenth-century United States. Those stories tend to privilege the actions of white abolitionists because theirs were the stories that were recorded in print. But the Colored Conventions help to document the vital role of the Black activists who were working within their own communities to end slavery and achieve liberation.

The creation of the corpus enables these important activists to be counted, as well as have their words (as recorded in the meeting minutes) analyzed and incorporated into the historical record. But the process of converting the meeting minutes into data strongly recalls the original violence that accompanied the slave trade, when human lives—in fact, the very ancestors of these activists—were reduced to numbers and

names. In recognition of this irreconcilable tension, the CCP requires that all those who download the corpus commit to a set of principles, including "a use of data that humanizes and acknowledges the Black people whose collective organizational histories are assembled" in the corpus, and a request to "contextualize and narrate the conditions of the people who appear as 'data' and to name them when possible."[59]

There is a second tension that the CCP navigates in an exemplary fashion, which has to do with the content of the corpus itself. Because it is derived from the conventions' official meeting minutes, it records only the "official" participants in the conventions and the discussions they initiated. These participants were almost exclusively men. To address this disparity, the CCP team asks its teaching partners to sign a Memo of Understanding (MoU) before introducing students to the project. The MoU requests that all instructors introduce a woman involved in the conventions, such as a wife, daughter, sister, or fellow church member, alongside every male delegate who is named (figure 4.9).[60] From this work of recovery, the CCP is creating a second dataset of the women's names—those who would otherwise go uncounted and therefore unrecognized for their work. They are using data collection to make these contributions count.

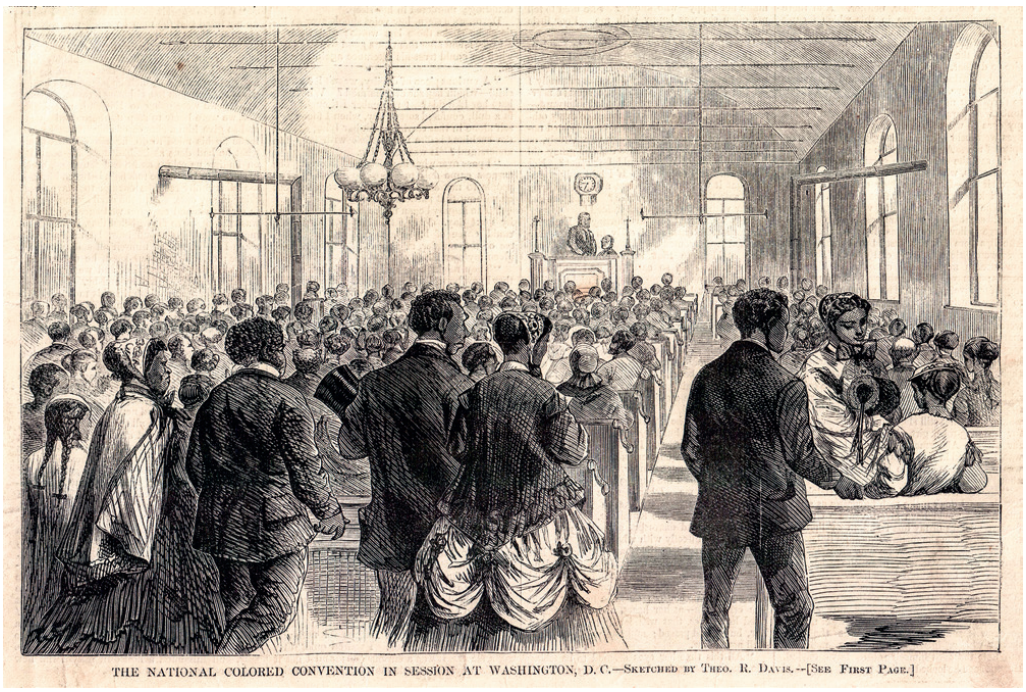

THE NATIONAL COLORED CONVENTION IN SESSION AT WASHINGTON, D. C.—Sketched by Theo. R. Davis.—[See First Page.]

Figure 4.9
An engraving of an 1869 Colored Convention, published in *Harper's Weekly*, showing men at the podium and women seated and standing in the rear. Image courtesy of Jim Casey.

Counting as Healing, Counting as Accountability

In the nineteenth century, as today, so many of the disparities introduced into datasets had to do with much larger and much more profound asymmetries of power. The asymmetries are often directly reflected in the power dynamics between who is doing the counting and who is being counted. But when a community is counting for itself, about itself, there is the potential that data collection can be not only be empowering but also healing. One example of this that draws from the personal experience of one of the authors of this book. It was 2014, and Catherine was a student and nursing her baby daughter at the time, as well as struggling to pump breastmilk for her in unsavory places like server rooms and bathroom floors. Frustrated, she and six student colleagues came together to publish a call for ideas and stories that could help to improve breast pump technology.[61] These stories led to a research paper about breast pump design, as well as the creation of the Make the Breast Pump Not Suck Hackathon (figure 4.10)—an

Figure 4.10
The 2018 Make the Breast Pump Not Suck Hackathon was the second gathering of the community at MIT and focused on racial equity in breastfeeding, as well as shifting paid leave policy in the United States. Photo by Rebecca Rodriguez and Ken Richardson, MIT Media Lab.

ongoing forum for sharing stories, hacking pumps, and reengineering the postpartum ecosystem that surrounds them.[62]

Although innovation spaces had long been holding hackathons for health technology, the 2014 event was one of the first about birth and breastfeeding. As such, it led to participants sharing stories in a space that was (temporarily) free of the stigma surrounding breastfeeding. These stories pointed to common experiences and patterns in the spirit of "the personal is political" consciousness-raising events. Participants recognized these stories as data that could be used—and in fact were used—to demand more from breast pump makers, from workplaces, and from society, to help transform the self-blame that women often experience as a result of difficulties with birth and breastfeeding into collective political action.[63]

But action by whom, and action for whom? Following the 2014 event, we (meaning the organizers) reflected on its successes and its limitations—in particular, its lack of an intersectional approach.[64] In the United States, maternal health carries significant race and class inequities, as discussed in chapter 1. The first hackathon did not consider those inequities; it centered the needs of some the most privileged mothers and produced designs that favored their experiences. We decided to try again. In 2017 and 2018, we multiplied the single event into a participatory research project, a policy summit, and a community innovation program, as well as a hackathon. In all of these, we deliberately centered the needs and the participation of parents of color, low-income parents, and LGBTQ+ parents. When we arrived at the hackathon the second time around, it was the result of over a year of relationship building and identity work on the part of the organizers with our community partners.

Ensuring that the 2018 hackathon would fully welcome the participation of these families required multiple forms of accountability. Guided by Jenn Roberts, our lead organizer for equity and inclusion, we wrote a values statement and convened an advisory board with leaders in breastfeeding, equity, and maternal health. We also developed a set of metrics to shape the demographics of the event.[65] These metrics were designed to prioritize racial diversity, gender diversity, diversity of sexual orientation, geographic diversity, and domain diversity, with additional priority given for young people and newcomers. On the application form, potential participants were encouraged to self-identify their gender and race, specify their location, and choose multiple options from a list of predefined domain expertise categories (like "parent" or "designer/artist"). We also invited them to write about why they wanted to attend, and if they chose to disclose information about their sexual orientation or their financial position, then we considered that information in the process.

Were these categories reductive? Of course they were. No person can fit their whole self into a form, regardless of how many blank text fields are provided. Did the form reflect the true nature of each person's intersecting identities and how those identities impact that person's being in the world? The answer to this question is also unsurprising: of course it did not. But the process of collecting this demographic data—which was, crucially, undertaken voluntarily and from within the community itself—resulted in an event that was indeed guided by the knowledge and experience of the groups that our coalition had hoped to center.[66]

Catherine shared this experience with Lauren as we were beginning to draft this book, and we decided to use a similar process to help hold ourselves accountable to the values that we wanted to inform *Data Feminism* and the criteria by which certain projects and texts would be selected for inclusion. We determined specific numbers and percentages that, in our view, would help keep us accountable to those values, as well as the categories of data collection that would be required to determine whether the metrics had been met. (These are viewable in the appendix, Our Values and Our Metrics for Holding Ourselves Accountable.) At two phases in the process—first when we posted the draft of the manuscript online, and second after we submitted the manuscript for copyediting—one of our research assistants, Isabel Carter, audited the projects and citations of the book. (They describe their research methods in more detail in "Auditing *Data Feminism*," included as another appendix.) As with the hackathon, these metrics were not the only method we employed for holding ourselves accountable. We also interviewed the creators of many of the projects we reference, cleared our quotes and portrayals of their work with them, and published a draft of the book online for open peer review, among other approaches.

Was our method of counting perfect? Of course not. We are certain we have made mistakes. This is among the reasons that we decided to keep our disaggregated data private, even as we published the aggregated results. What about the idea to count people and projects in the first place? Shouldn't that be viewed as contributing to the same reduction in complexity that we have argued against thus far in this book? As this chapter has demonstrated, counting is always complicated. But undertaken deliberately, tailored to specific goals, and with issues of privacy and potential harms always in mind, counting can be used to support accountability—as one method, among many, of working toward a larger goal.

Rethink Binaries and Hierarchies

Counting and classification can be powerful parts of the process of creating knowledge. But they're also tools of power in themselves. Historically, counting and classification

have been used to dominate, discipline, and exclude. This is where the fourth principle of data feminism, *rethink binaries and hierarchies*, enters in. The gender binary offers a key example of how classification systems are constructed by cultures and societies and reflect both their values and their biases. The cases of the TSA airport scanners, Facebook user profiles, and plain old pants show us how gender and sex binaries—along with scientifically incorrect understandings of both gender and sex—get encoded into technical systems (and also jeans)! Those systems, in turn, recirculate erroneous and harmful ideas.

An intersectional feminist approach to counting insists that we examine and, if necessary, rethink the assumptions and beliefs behind our classification infrastructure, as well as consistently probe who is doing the counting and whose interests are served. Counting and measuring do not always have to be tools of oppression. We can also use them to hold power accountable, to reclaim overlooked histories, and to build collectivity and solidarity. When we count within our own communities, with consideration and care, we can work to rebalance unequal distributions of power.

Narrative Visualization: Telling Stories with Data

Edward Segel and Jeffrey Heer

Abstract—Data visualization is regularly promoted for its ability to reveal stories within data, yet these "data stories" differ in important ways from traditional forms of storytelling. Storytellers, especially online journalists, have increasingly been integrating visualizations into their narratives, in some cases allowing the visualization to function in place of a written story. In this paper, we systematically review the design space of this emerging class of visualizations. Drawing on case studies from news media to visualization research, we identify distinct genres of narrative visualization. We characterize these design differences, together with interactivity and messaging, in terms of the balance between the narrative flow intended by the author (imposed by graphical elements and the interface) and story discovery on the part of the reader (often through interactive exploration). Our framework suggests design strategies for narrative visualization, including promising under-explored approaches to journalistic storytelling and educational media.

Index Terms—Narrative visualization, storytelling, design methods, case study, journalism, social data analysis.

1 Introduction

In recent years, many have commented on the storytelling potential of data visualization. News organizations including the New York Times, Washington Post, and the Guardian regularly incorporate dynamic graphics into their journalism. Politicians, activists, and television reporters use interactive visualizations as a backdrop for stories about global health and economics [10] and election results [9]. A recent feature in The Economist [6] explores the proliferation of digital data and notes that visualization designers are *"melding the skills of computer science, statistics, artistic design and storytelling."*

Static visualizations have long been used to support storytelling, usually in the form of diagrams and charts embedded in a larger body of text. In this format, the text conveys the story, and the image typically provides supporting evidence or related details. An emerging class of visualizations attempts to combine narratives with interactive graphics. Storytellers, especially online journalists, are increasingly integrating complex visualizations into their narratives.

Crafting successful "data stories" requires a diverse set of skills. Gershon and Page [12] note that effective story-telling *"require[s] skills like those familiar to movie directors, beyond a technical expert's knowledge of computer engineering and science."* While techniques from oration, prose, comic books, video games, and film production are applicable to narrative visualization, we should also expect this emerging medium to possess unique attributes. Data stories differ in important ways from traditional storytelling. Stories in text and film typically present a set of events in a tightly controlled progression. While tours through visualized data similarly can be organized in a linear sequence, they can also be interactive, inviting verification, new questions, and alternative explanations.

Currently, most sophisticated visualization tools focus on data exploration and analysis. Applications such as spreadsheets and visualization tools support an array of analysis routines and visual encodings, but beyond exporting images for presentation typically provide scant support for crafting stories with analysis results. As such, they provide powerful vehicles for discovering "stories", but do little to aid narrative communication of these findings to others. As tools mature and more richly integrate with the web (e.g., Many Eyes [25], Tableau Public [22], GeoTime Stories [8]), they are enabling the publication of dynamic graphics with variably constrained levels of interactivity. It remains an open question how the design of such tools might be evolved to support richer and more diverse forms of storytelling.

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For information on obtaining reprints of this article, please send email to: tvcg@computer.org.

In this paper, we investigate the design of narrative visualizations and identify techniques for telling stories with data graphics. We take an empirical approach, analyzing visualizations from online journalism, blogs, instructional videos, and visualization research. After reviewing related work, we share five selected case studies which highlight varied design strategies and illustrate our analytic approach. We then formulate a design space constructed from an analysis of 58 examples. Our analysis identifies salient dimensions of visual storytelling, including how graphical techniques and interactivity can enforce various levels of structure and narrative flow. We describe seven genres of narrative visualization: magazine style, annotated chart, partitioned poster, flow chart, comic strip, slide show, and video. These genres can be combined with interactivity and messaging to produce varying balances of author-driven and reader-driven experiences. Finally, we discuss the implications of our framework, noting recurring design strategies, promising yet under-utilized approaches to integrating visualization with other media, and the potential for improved user interfaces for crafting data stories. By focusing on the graphical and interactive elements of narrative visualization, our approach gives less attention to the cognitive and emotional experience of the reader. We recognize the importance of these elements, however, and describe directions for future reader-centric research in our conclusion.

2 Related Work

Storytelling and visual expression are integral parts of human culture; storytelling has even been referred to as *"the world's second-oldest profession"* [12]. Without summarizing millennia of achievement, we describe a few of the key concepts informing narrative visualization.

2.1 Narrative Structure

The Oxford English Dictionary defines *narrative* as "an account of a series of events, facts, etc., given in order and with the establishing of connections between them." Central to this definition is the notion of a chain of causally related events. Stories of this form often have a beginning, middle, and end [3, 24]: an introduction to the situation, a series of events often involving tension or conflict, and a resolution.

Since ancient times, people have tried to understand and formalize the elements of storytelling. For example, writers (e.g., [5, 19, 21]) have developed typologies of dramatic situations and identified plot lines common to many narratives, such as the "hero's journey" [5]. This research typically distinguishes between the content of the story and the form in which it is told. While stories often concern interacting characters, they may also present a sequence of facts and observations linked together by a unifying theme or argument.

Storytelling strategies vary among media and genre. For instance, stories told through writing have access to a different set of formal mechanisms and narrative structures (e.g., stream of consciousness) than stories told through film (e.g., split-screen sequences [3]). Blundell [2] describes narrative devices for journalism such as the *anecdo-*

tal lead—an initial story, often involving dialogue and characters, that presents a microcosm of the larger news story—and the *nut graf*—a paragraph explicitly describing the news value of an article. These devices are largely unique to journalism, as opposed to literary fiction or film. Visualizations themselves may incorporate a variety of media, including text, images and video, and can also be interactive, enabling stories whose telling relies as much on the reader as on the author.

2.2 Visual Narratives

Artists, designers, and psychologists have all explored ways in which visual media can be organized to engender a narrative experience. They have developed nuanced techniques for sequentially directing a viewer's attention and keeping viewers oriented across transitions. While a full treatment of these devices is beyond the scope of this paper, we present some salient principles here.

Many narratives are rooted in a clear starting point. In visual media, an establishing shot or overview [3, 19] is often used to introduce the scene. Of course, not all elements in a scene are of equal importance throughout a story, and so authors often manipulate a scene to direct attention to a point of interest. Psychologists have extensively studied phenomena of visual salience [11, 17, 23], showing that outliers among visual features such as color, size, and orientation preferentially attract one's attention. The strength of this attraction is modulated by multiple factors [17], including the scene itself (e.g., a brightly colored object is less salient when surrounded by other brightly colored objects) and by the viewer's task (e.g., expectations and top-down search can affect what is perceived as most salient).

Cultural factors, particularly reading order (e.g., left-to-right) naturally bias where people look first and how they scan an image [19]. Visual techniques can further establish the order in which the eye visits elements in the scene. For example, gestalt grouping [26] via features such as spatial proximity, containment, or connection may bias one towards first perceiving the grouped content. Vectorial reference [18, 24], most commonly in the form of arrows, is a powerful technique for sequentially directing attention.

Visual media often involve changes of scene, such as between the panels of a comic or across cuts in edited film. A number of devices have been developed to orient a viewer during transitions. Continuity editing techniques in film [3], such as matching on objects or actions, suggest the connection between scenes and may sustain a focus of attention. Similarly, animation design [14, 24] often relies on object constancy and de-emphasizes secondary details to keep viewers oriented; animators may also subdivide a transition into stages to facilitate apprehension. Within comics, McCloud [19] proposes a taxonomy of transition types consisting of *moment-to-moment* (one subject, short time period), *action-to-action* (one subject, longer time period), *subject-to-subject* (different subjects, same scene), *scene-to-scene* (change of scene), *aspect-to-aspect* ("aspects of a place, idea, or mood"), and *non-sequitur* (logically unconnected) transitions. In addition to continuity of objects or actions, extra-pictorial elements [24] such as callouts (e.g., insets or lines to denote zooming) and annotations are used to enrich a narrative. Not surprisingly, we will see that many of these techniques are also applicable to narrative visualization.

2.3 Storytelling with Data Visualization

Though data visualization often evokes comparisons to storytelling [6, 7], the relationship between the two is rarely articulated clearly. Jonathan Harris, the creator of *We Feel Fine* and *Whale Hunt*, considers himself a storyteller first and a visualization designer second: *"I think people have begun to forget how powerful human stories are, exchanging their sense of empathy for a fetishistic fascination with data, networks, patterns, and total information... Really, the data is just part of the story. The human stuff is the main stuff, and the data should enrich it."* Yet when pressed to describe what he means by "story," he responds with only a rough approximation: *"I define 'story' quite loosely. To me, a story can be as small as a gesture or as large as a life. But the basic elements of a story can probably be summed up with the well-worn Who / What / Where / When / Why / How."*

Others have tried to articulate the connection more concretely. Gershon and Page [12] observe that stories communicate information in a psychologically-efficient format, also a central goal of visualization design. Using the script of a fictional military scenario as a case study, they examine tactics used to communicate narrative events, including continuity editing, highlighting (e.g., flashing), and redundant messaging across media (e.g., audio and video). Still, a deeper understanding of narrative visualization remains elusive, as *"we need to further understand the characteristic interactions of each genre with each particular audience, its advantages and disadvantages, and how it might affect content and learning."* Wojtkowski and Wojtkowski [27] further argue that what makes data visualization different from other types of visual storytelling is the complexity of the content that needs to be communicated. They conclude that *"visual storytelling, in turn, might be of critical importance in providing intuitive and fast exploration of very large data resources,"* but again stop short of detailing how we might best *"tailor visualization systems to accommodate storytelling."*

Some visualization systems have begun to incorporate storytelling into their design. For example, GeoTime Stories [8] enables analysts to create annotated stories within visualizations using a text editor and bookmarking interface. The sense.us [15] system allowed users to create trails of visualization bookmarks that were regularly used for storytelling. Tableau's graphical histories [13] lets users review, collate, and export key points of their visual analysis. More recently, Tableau Public [22] supports the construction and web-based publication of interactive visualizations, supporting storytelling in data-rich domains such as finance and sports journalism. Such systems provide the first steps toward making richer storytelling capabilities accessible.

In short, many have observed the storytelling potential of data visualization and drawn parallels to more traditional media. However, a thorough understanding of the design space for narrative visualization has yet to emerge. In the meantime, practitioners such as artists and journalists have been forging paths through this space, and we might hope to gain insight from their explorations. Here we seek to further our understanding of narrative visualization by analyzing and contrasting examples of visualizations with a story-telling component. We then generalize from these examples to identify salient design dimensions. In the process, we hope to clarify how narrative visualization differs from other storytelling forms, and how these differences introduce both opportunities and pitfalls for its narrative potential.

3 Case Studies of Narrative Visualization

We collected visualizations with narrative components, and then attempted to identify and categorize the design features that effectively tell stories with data. We gathered examples from sources such as online journalism, blogs, visualization books, research papers, and software packages. Our primary source was online journalism, including visualizations produced by the New York Times, the Guardian, the Financial Times, the Washington Post, and Slate. Additional visualizations were found through visualization blogs such as Flowing Data, Infosthetics, and Visual Complexity. For completeness, we also examined visualizations that do not explicitly tell stories but nonetheless contain relevant storytelling components. We analyzed the narrative and interactive devices used in each example. The accumulated data reveals recurring patterns, leading to our analysis in Section 4.

In this section, we present five selected case studies of narrative visualization. Our goal is to highlight both exemplary and problematic approaches, as well as give the reader a sense of our method of analysis. Throughout, recurrent design strategies are marked in **bold face**. The examples were chosen to provide a diverse sample of points in the design space of narrative visualization. These case studies also highlight the potential application of narrative visualization in fields ranging across journalism, sports, public policy, and finance.

3.1 Steroids or Not, the Pursuit is On

Baseball star Barry Bonds points to the sky; his goal, 755 home runs, hovers over his head—"Steroids or Not, the Pursuit is On" [A36]. Shadowing Bonds' attempt were allegations of steroid use, and many sports statisticians turned to the numbers to investigate these claims.

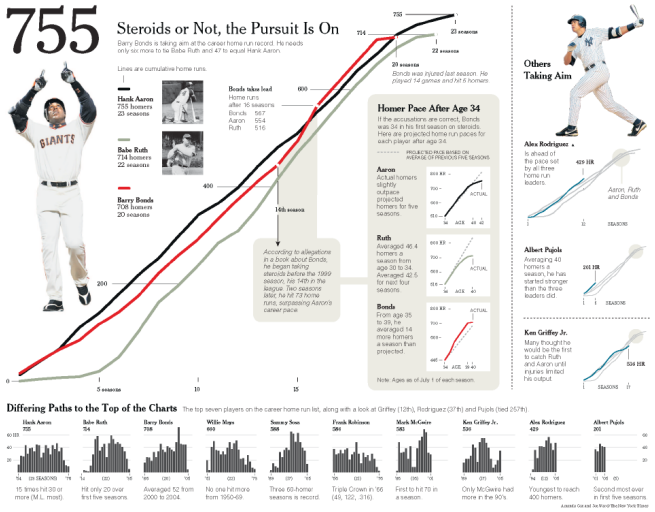


Fig. 1. Steroids Or Not, the Pursuit is On. New York Times.

Sized prominently and placed in the upper left corner of the page, the image of Bonds grabs the eye and points the viewer towards the title, establishing the topic for the rest of the graphic. A legend consisting of photos and text introduce Hank Aaron and Babe Ruth, previous home run leaders whose careers provide points of comparison for Bonds' career. A line-chart of accumulated home runs shows the three hitters' careers in alignment, with Bonds' home runs accelerating at a time when the other hitters slow down. A shaded **annotation** notes that the acceleration coincides with the first reports of steroid use in Bonds' 14th season, accompanied by a second annotation just two years later when Bond takes the lead over Ruth and Aaron. The shaded path then flows to a similarly-colored inset to the right containing a comparison of each player's home run pace after age 34, emphasizing the suspicious acceleration in Bonds' hitting so late in his career.

The viewer may then move to other sections. On the right, the eye is invited by a large image of a swinging Alex Rodriguez and a bold caption noting "Others Taking Aim." Here we see the other current players who are chasing the career home run record. The bottom section ("Differing Paths to the Top of the Charts"), devoid of color and consisting of smaller plots, is given minimum visual priority but completes the story. Small multiples show the home runs per season for top players on the career home run list, each captioned by a factoid.

The visualization resembles a poster one might see at a science fair, with the space subdivided into smaller sections, each telling its own sub-story with charts, pictures, and text. The three sections are linked together graphically through the use of color, shape, and text. For example, the largest section introduces the hitters according to their order on the career home run list: Hank Aaron (black line), Babe Ruth (green line), and Barry Bonds (red line). Subtly **matching on content**, the inset in this section maintains this same scheme, presenting the players in the same order with their associated colors. This allows the viewer to immediately discern the reference to the larger image. The section below also begins in the same order (Aaron, Ruth, Bonds) before proceeding to the other players. This order not only carries informational content (i.e., who has the most home runs) but also prevents the viewer from having to reorient while switching between sections. Finally, the section to the right charts the performance of current players over a shadow of the initial chart, a shape we immediately identify as belonging to Aaron, Ruth, and Bonds.

While these elements provide seamless transitions between sections, they do not dictate the order in which the viewer explores the visualization. Rather, a path is accomplished through the use of **visual highlighting** (color, size, boldness) and connecting elements such as arrows and shaded trails. When looking at the visualization, the viewer begins with the largest image, in part because of its size, central positioning, and coloring, but also because it is capped with a large headline and a picture of Bonds himself telling the viewer where to look.

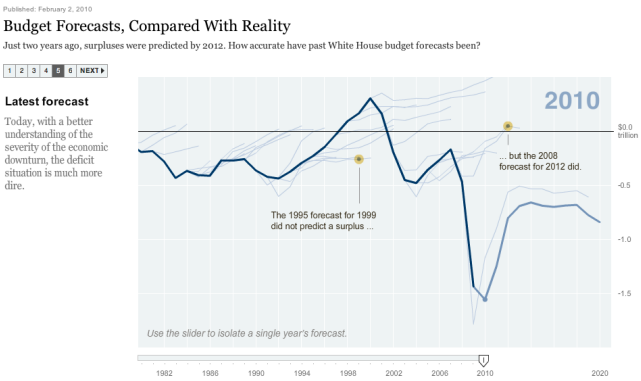


Fig. 2. Budget Forecasts, Compared With Reality. New York Times.

3.2 Budget Forecasts, Compared With Reality

When deteriorating economic conditions forced a downward revision in the 2010 White House budget forecast, the New York Times published this visualization [A53] to explore the accuracy of past budgets' predictions. A large headline is followed by a brief prompt introducing the visualization. Below are two panels side by side. The left panel contains another bold headline accompanied by a short paragraph of text, while the right panel contains a line chart showing budget surpluses and deficits between 1980-2020, with the estimates distinguished from actual data using annotations and coloring. Just above these panels is a **progress bar** indicating the length of the visualization and providing the user with a mechanism to navigate between slides.

As the user steps through the presentation, the visualization maintains a **consistent visual platform**, changing only the content within each panel while leaving the general layout of the visual elements intact. Each new slide alters the text in the left panel, while updating the chart in the right panel with animated transitions. A narrative is communicated clearly through the interaction of the text in the left panel with the annotations and graphic elements in the right panel, each enriching the narrative through **multi-messaging**, providing related but different information [20]. In this way, the presentation guides the viewer through historical budget forecasts, explaining patterns in the data (*80% of deficit forecasts have been too optimistic*) and highlighting key events (*surpluses under Clinton were generated in part by a stock market bubble*). Users can discover additional statistics by mousing-over the chart, revealing **details-on-demand** with the years and estimates of past forecasts. Halfway through the presentation, a **timeline slider** appears above the dates on the horizontal axis, with the slider position updating along with the chart above. Text on the fifth slide explicitly encourages the user to interact with this slider to isolate forecasts for a single year. The presentation ends with the current budget forecasts for 2012, letting the user see how these predictions change under different economic assumptions.

At its core, this visualization is a typical slide-show presentation augmented by two important features. First, it allows the user to determine the pace of the presentation by using the provided progress bar. And second, it allows the user to interact with the presentation by mousing-over areas of interest and by using the slider to explore different time windows. We call this structure an **interactive slideshow** that uses **single-frame interactivity**, meaning that interaction manipulates items within a single-frame without taking the user to new visual scenes. These devices encourage the user to explore the data within the structure of an overarching narrative. The narrative functions in two ways, both communicating key observations from the data, as well as cleverly providing a **tacit tutorial** of the available interactions by animating each component along with the presentation. By the time the presentation encourages the user to investigate budget forecasts for specific years, it is already clear to the user how to do this.

This presentation style can be compared to a narrative pattern called the **martini glass structure** [4], following a tight narrative path early on (the stem of the glass) and then opening up later for free exploration (the body of the glass). Different features of the visualization

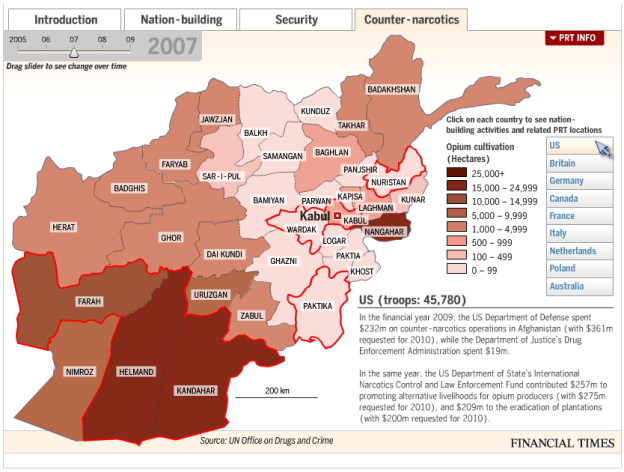


Fig. 3. Afghanistan: Behind the Front Line. Financial Times.

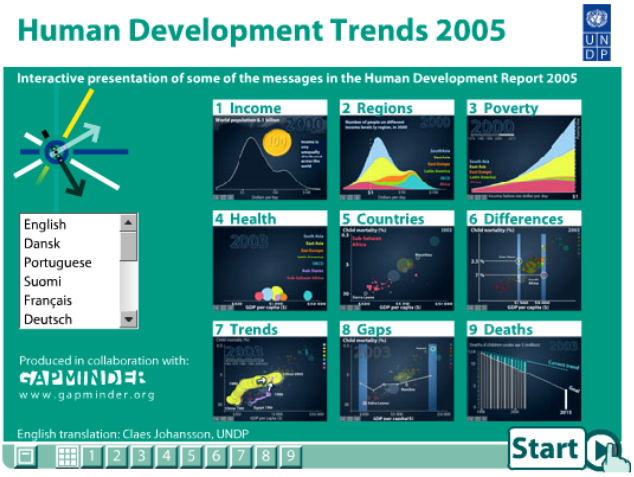


Fig. 4. Human Development Trends. Gapminder.

ensure that the viewer does not lose his place in the narrative during this exploratory stage, with orientation provided by the consistency of the visual platform, the updating progress bar, and the timeline slider.

3.3 Afghanistan: Behind the Front Line

In an effort to draw popular support away from the Taliban, NATO deployed groups of soldiers and civilians known as Provincial Reconstruction Teams (PRTs) to Afghanistan to implement nation-building development projects. People began to question the effectiveness of these groups amidst escalating violence in the region. This visualization [A45] begins with a traditional newspaper headline and brief article introducing the PRT's mission. The article then states the intended purpose of the graphic: to establish indicators of success by which to evaluate the development work being done in Afghanistan.

The graphic starts with its own introduction as well, occupying the first of four tabs the user can select. This starting tab contains only introductory text and a photograph of a US soldier. The remaining tabs (Nation-building, Security, Counter-narcotics) each contain an identical map of Afghanistan subdivided by province. A different hue (green, blue, red) is used to color the map for each tab, providing a **semantically consistent** color encoding; brightness encodes the values for each province. To the upper left of the map is a legend which changes according to the tab's content. The "Nation-Building" tab tracks the overall cost of activities for each province, "Security" tracks the severity of insurgent activity, and "Counter-Narcotics" tracks opium cultivation. This last tab also contains a **timeline slider**, allowing the user to explore how opium cultivation has changed over the past five years of the PRT's efforts.

Each tab contains an interactive list of NATO countries on the right. A short message and mouse pointer indicate the list is interactive. Clicking an individual country highlights the provinces in which that country has troops deployed, outlining their borders with a flashing red line. A paragraph of text appears in a panel below, providing facts about that country's involvement, and in some cases allowing the user to isolate particular activities (Education, Health, Economic Development, etc.). Finally, a button labeled "PRT INFO" slides down a new window containing additional background about the PRTs in Afghanistan, with **details-on-demand** for each country involved.

The visualization maintains the same graphical layout across tabs, modified only slightly for the different content. This **consistent visual platform** provides easy transitions between tabs, and the colors serve as an indication that a switch has occurred. The visual highlighting of provinces serves to draw the viewer's eye to the relevant areas, a necessary feature given the density of the map. Finally, each interactive component is clearly adorned with **markers of interactivity**, explicitly pointing out the potential for interaction.

However, we believe that some aspects of the visualization could be improved. Most importantly, the overall structure does not sufficiently guide the viewer through the data, making it hard to draw meaningful conclusions from the large amount of information available. Why do some regions cost more than others? (Annotations are needed on the map.) Which countries provide the best aid? (Comparisons are needed between countries.) What projects exist in a particular region? (Regions cannot be selected.) Moreover, too much information is provided for each country in terminology-heavy paragraphs that are difficult to parse. While this may be useful for a trained analyst, a general audience would be better served by replacing the vast quantity of information with memorable factoids. The graphic may suffer by putting exploratory power into the hands of the viewer without sufficient guidance. A **synthesis or summary** could be very useful toward this end.

3.4 Gapminder Human Development Trends

This **interactive slideshow** [A47] surveys trends in global income and health. The visualization begins with a grid of screenshots from different sections of the presentation (Figure 4), with each image labeled with its respective topic (Income, Poverty, Health, Deaths, etc.). This **checklist structure** [20] provides an establishing shot of the content to be covered and serves as a reminder of what each section contains once the presentation is finished. It also enables navigation to particular segments. A **progress bar** at the bottom of the screen mirrors the grid above, while a large "Start" button in the lower right corner, highlighted by an animated pointer, tells the viewer how to begin the presentation. This button turns into familiar browser-style "forward" and "back" buttons when clicked, letting the user navigate between slides at his own pace. A second progress bar also appears upon entering each individual section. Both progress bars also serve as navigation tools, allowing the user to skip around the presentation without relying on the stepwise navigation provided by the browser buttons.

The presentation contains three basic kinds of charts: histograms, scatter plots, and bar charts. However, no individual section utilizes more than one chart type. Importantly, changes between chart types are made explicit in order to avoid confusing the viewer. For example, when the presentation transitions from histograms to scatterplots between Sections 3 and 4, a staged **animated transition** morphs the chart types across several patient steps (see Figure 5). Even manipulations within a single chart receive this same attention: in Section 3, a comment *"Zooming in below the poverty line"* alerts the viewer to the upcoming manipulation before it occurs.

Fig. 5. Staged animated transitions between chart types.

Each section walks the user through a visualized dataset, pointing out key observations along the way. These explanations rely on a combination of **annotations**, **highlighting**, **animated transitions**, and **single-frame interactivity**. Typically, the data is not presented all at once. Rather, each chart is constructed in a stepwise fashion, with annotations and animations explaining each stage of the process. In Section 1, the x-axis initially appears without the rest of the chart, introduced with the comment, *"Daily income is measured in dollars per day."* In Section 2, the graphic incorporates the data for each geographic region individually, reserving the pauses between animations to offer facts about the region (*Africa: Population 630 million*). At any point in these lessons, the user can mouse over different graphical elements for **details-on-demand**.

Beyond simply introducing graphical features, the annotations convey a narrative for each section, providing observations that the viewer would unlikely identify on his own. For example, Section 3 explains *"In the 1970s most poor lived in South and East Asia."* Then, as the timeline moves forward and the chart changes, a new comment states, *"The last 30 years changed the face of global poverty. Now Africa is the home of one third of all poor."* A final animation updates the chart even further, this time with the comment, *"In 2015 Africa will account for the majority of the world poverty."* These narratives crucially allow dense information to be quickly comprehended by the user, and the graphical elements play an important role in making this possible: animations highlight relevant sections of the charts, color schemes remain **semantically consistent** between slides, and arrows and labels regularly appear to clarify elements mentioned in text.

Periodically the presentation allows increased user interactivity with the display, typically after a narrative segment is complete, again following a **martini glass structure**. In this presentation, the increased interactivity occurs most frequently in segments using time-series data, as a **timeline slider** appears to let the user return to previous years. Importantly, the exposed interactivity is part of the narrative, not merely an afterthought. For instance, Section 3 explains *"The global goal of halving poverty by 2015 will be met because of fast progress in Asia. But on current trends Africa and Latin America will not meet that goal."* At this point, additional interactive components appear on the display and a prompt appears with the message *"Use the timebar to see people in Asia moving out of poverty."* In this way, the interactivity is actually a continuation of the story, emphasizing the same themes and encouraging the user to use the story as a starting point for his own personal exploration of the data.

3.5 The Minnesota Employment Explorer

Months before the stock market crash of September 2008, many observers noted that the economy was slowing down; unemployment was rising while gas and food prices neared record highs. In January 2008, Minnesota's state economist had seen enough to say the state was in recession. In response, in July 2008 Minnesota Public Radio (MPR) released a feature on their website on the "Minnesota Slowdown." The page links to stories detailing the state's economic malaise and shares interviews with residents hit hard by the downturn.

At the bottom of the page lies an interactive visualization of state unemployment data: The Minnesota Employment Explorer [A19], a joint effort of MPR and the UC Berkeley Visualization Lab. Small multiples of time-series charts show normalized unemployment data by industry from 2000 to 2007. Both long-term trends and seasonal oscillations are apparent. For example, the Health sector exhibits steady growth, while agriculture, construction, and education show strong seasonal patterns. Mouse-hover provides **details-on-demand**; double-clicking an industry triggers a drill-down into that sector, with an **animated transition** updating the display to show sub-industry trends.

Notably, the visualization also includes social interaction features. A list of comments associated with the current view enables journalists and readers to share observations and discuss trends. Commentary and visualization are linked together: one can select a data series to highlight it in the view; the highlight is subsequently saved with the comment. Selecting a comment reveals these annotations. Conversely, selecting a series highlights related commentary.

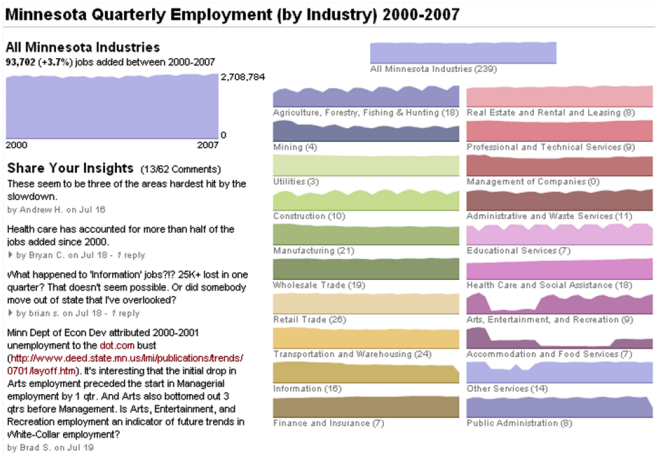


Fig. 6. Minnesota Employment Explorer. Minnesota Public Radio.

The goal of the visualization was to engage readers in finding and telling their own stories in the data. It was hoped that residents in various occupations would engage in social data analysis [15], sharing expertise from their respective industries. Despite good intentions, the visualization largely failed in this goal. A total of 23 people submitted 62 comments, with 25 of these comments being posted by the producers of the visualization. Other guests pointed out trends of interest and shared pointers to other related data sets; for example, a registered nurse shared his first-hand experiences in the Health sector. However, the majority of posters were not citizens of Minnesota; they were visualization and statistics enthusiasts drawn by the technology (the piece was mentioned on a popular visualization blog) and not by the story.

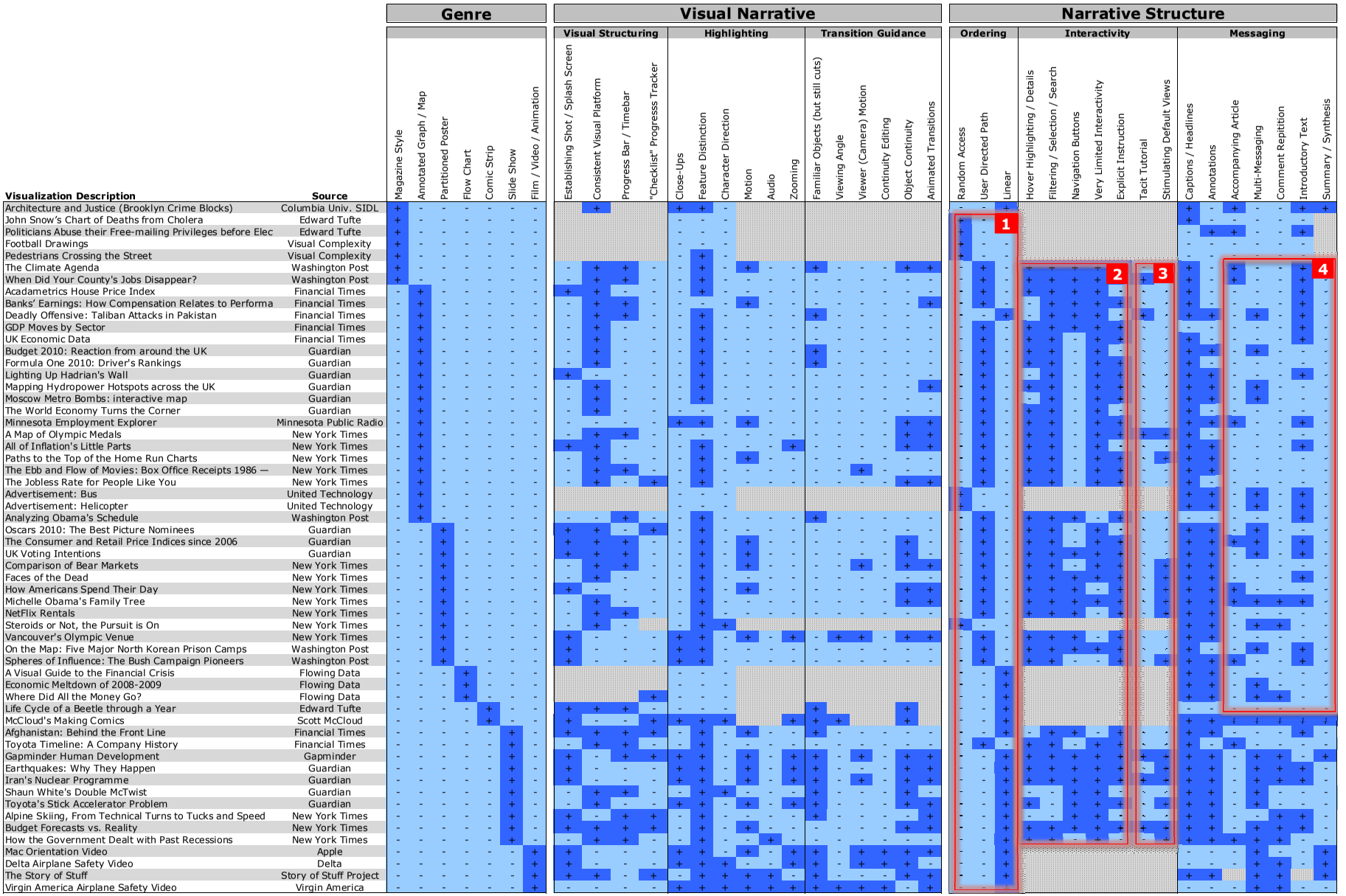
A post-mortem analysis reveals multiple areas for improvement. Some issues revolve around usability: the visualization was placed below-the-fold on the web site, and thus possibly overlooked by MPR readers. The visualization also lacked a **tacit tutorial**—it dropped readers into the data with little orientation and no example of a rich, emergent story. Seed comments served to highlight interesting patterns and raise questions, but did not develop a larger narrative.

Most importantly, the graphics are disconnected from the narrative. While unemployment statistics are topically relevant to the feature, they were not related to any of the other news stories. Moreover, only unemployment data from 2000-2007 was available from the state at that time—yet the main concern of the feature is the economic woes of 2008. Though the Employment Explorer was designed with the hopes of having people *annotate data with stories*, this example suggests that it may be more fruitful to first *annotate stories with data*. By immersing readers in a narrative and providing a tacit tutorial, readers may become invested in exploring new perspectives of a story—and perhaps branch out in search of new stories of their own.

4 Design Space Analysis

We seeded our choice of design space dimensions using related work in film, comics, and art. In particular, McCloud's "Making Comics" [20] provides a robust taxonomy of visual elements that contribute to storytelling. Our ideas evolved as we analyzed more examples and observed emerging patterns. These observations allowed us to further organize the design features into increasingly coherent categories, such as genre types for narrative visualizations and different methods of integrating visualizations with accompanying text. Our final categories depict unique patterns for narrative visualization, distinguishing itself from other forms visual storytelling. For example, interactive visualizations allow users to manipulate the display, introducing design decisions that do not apply to non-interactive media.

We represent the design space in a table that relates each example to specific design strategies observed across the dataset. In total we analyzed 58 visualizations using the case study method illustrated in Section 3. The examples were taken from online journalism (71%), business (20%), and visualization research (9%). We optimized our



Visualization Description	Source
Architecture and Justice (Brooklyn Crime Blocks)	Columbia Univ. SIDL
John Snow's Chart of Deaths from Cholera	Edward Tufte
Politicians Abuse their Free-mailing Privileges before Elec	Edward Tufte
Football Drawings	Visual Complexity
Pedestrians Crossing the Street	Visual Complexity
The Climate Agenda	Washington Post
When Did Your County's Jobs Disappear?	Washington Post
Acadametrics House Price Index	Financial Times
Banks' Earnings: How Compensation Relates to Performa	Financial Times
Deadly Offensive: Taliban Attacks in Pakistan	Financial Times
GDP Moves by Sector	Financial Times
UK Economic Data	Financial Times
Budget 2010: Reaction from around the UK	Guardian
Formula One 2010: Driver's Rankings	Guardian
Lighting Up Hadrian's Wall	Guardian
Mapping Hydropower Hotspots across the UK	Guardian
Moscow Metro Bombs: interactive map	Guardian
The World Economy Turns the Corner	Guardian
Minnesota Employment Explorer	Minnesota Public Radio
A Map of Olympic Medals	New York Times
All of Inflation's Little Parts	New York Times
Paths to the Top of the Home Run Charts	New York Times
The Ebb and Flow of Movies: Box Office Receipts 1986 —	New York Times
The Jobless Rate for People Like You	New York Times
Advertisement: Bus	United Technology
Advertisement: Helicopter	United Technology
Analyzing Obama's Schedule	Washington Post
Oscars 2010: The Best Picture Nominees	Guardian
The Consumer and Retail Price Indices since 2006	Guardian
UK Voting Intentions	Guardian
Comparison of Bear Markets	New York Times
Faces of the Dead	New York Times
How Americans Spend Their Day	New York Times
Michelle Obama's Family Tree	New York Times
NetFlix Rentals	New York Times
Steroids or Not, the Pursuit is On	New York Times
Vancouver's Olympic Venue	New York Times
On the Map: Five Major North Korean Prison Camps	Washington Post
Spheres of Influence: The Bush Campaign Pioneers	Washington Post
A Visual Guide to the Financial Crisis	Flowing Data
Economic Meltdown of 2008-2009	Flowing Data
Where Did All the Money Go?	Flowing Data
Life Cycle of a Beetle through a Year	Edward Tufte
McCloud's Making Comics	Scott McCloud
Afghanistan: Behind the Front Line	Financial Times
Toyota Timeline: A Company History	Financial Times
Gapminder Human Development	Gapminder
Earthquakes: Why They Happen	Guardian
Iran's Nuclear Programme	Guardian
Shaun White's Double McTwist	Guardian
Toyota's Stick Accelerator Problem	Guardian
Alpine Skiing, From Technical Turns to Tucks and Speed	New York Times
Budget Forecasts vs. Reality	New York Times
How the Government Dealt with Past Recessions	New York Times
Mac Orientation Video	Apple
Delta Airplane Safety Video	Delta
The Story of Stuff	Story of Stuff Project
Virgin America Airplane Safety Video	Virgin America

Fig. 7. Design space analysis of narrative visualization. Columns indicate recurring design elements and selected regions highlight patterns in the data. Region (1) shows clusters of ordering strategies that correspond to distinct genres of visual narration. Region (2) highlights the consistency of interactive designs used by visualizations. Region (3) shows the under-utilization of strategies to engage the user in the interactive functionality. Region (4) shows the under-utilization of common storytelling techniques across narrative visualizations.

collection to include visualizations that contained clear sequences of narrative events, a diversity of visualization genres (e.g., flow charts, slide shows), and a range of interaction strategies (e.g., filtering, timelines). Using these criteria, we sampled from our initial larger pool of examples to arrive at the resulting 58 items featured in Fig. 7. However, we do not claim that our sample is exhaustive, as we did not canvas other potential sources such as video games or e-learning tools.

The table uses dark blue and a plus-sign (+) to indicate the presence of a particular feature; light blue and a minus-sign (-) indicate that an example does not use that feature. In some cases a cell is colored grey to indicate that a design feature is precluded by the medium rather rather than omitted by explicit design choices. For instance, we did not analyze visualizations on printed paper with respect to interaction or animation. That said, some workarounds to medium limitations are possible: comics can use a multi-panel series of increasing close-ups to convey the same effect as camera zoom [20], and static visualizations might employ a choose-your-own-adventure format to allow viewers to determine their own path through the content.

We arrived at our categories after much iterative organization (e.g., affinity diagramming [1]) of individual design features. We attempted to be consistent in our evaluation of each example. As our categories evolved, we reconsidered previous examples, re-categorizing as appropriate. We acknowledge there is some inevitable subjectivity when imposing a taxonomy over a diverse set of designs.

4.1 Design Space Dimensions

Our organization of the design space contains three divisions of features: (1) genre, (2) visual narrative tactics, and (3) narrative structure tactics. The first division identifies the *genre* of each visualization, a taxonomy of visual narrative types described later in section 4.3.

The second division identifies *visual narrative* tactics: visual devices that assist and facilitate the narrative. This division is subdivided into three sections: (i) visual structuring, (ii) highlighting, and (iii) transition guidance. *Visual structuring* refers to mechanisms that communicate the overall structure of the narrative to the viewer and allow him to identify his position within the larger organization of the visualization. These design strategies help orient the viewer early on (establishing shot, checklist, consistent visual platform) and allow the viewer to track his progress through the visualization (progress bar, timeline slider). *Highlighting* refers to visual mechanisms that help direct the viewer's attention to particular elements in the display. This can be achieved through the use of color, motion, framing, size, audio, and more, which augment the salience of an element relative to its surroundings. Many of these strategies are also used in film, art, and comics. *Transition guidance* concerns techniques for moving within or between visual scenes without disorienting the viewer. A common technique from film is continuity editing, though other strategies (e.g., animated transitions, object continuity, camera motion) also exist.

The third division identifies *narrative structure* tactics used by each visualization, or non-visual mechanisms that assist and facilitate the narrative. This division is further divided into three sections: (i) ordering, (ii) interactivity, and (iii) messaging. *Ordering* refers to the ways of arranging the path viewers take through the visualization. Sometimes this path is prescribed by the author (linear), sometimes there is no path suggested at all (random access), and other times the user must select a path among multiple alternatives (user-directed). *Interactivity* refers to the different ways a user can manipulate the visualization (filtering, selecting, searching, navigating), and also how the user learns those methods (explicit instruction, tacit tutorial, initial configuration). Finally, *messaging* refers to the ways a visualization communicates observations and commentary to the viewer. This might be achieved through short text fields (labels, captions, headlines, annotations) or more substantial descriptions (articles, introductions, summaries).

4.2 Design Space Observations

Three important patterns stand out from the data: (1) the clustering of different ordering structures, (2) the consistency of interaction design, and (3) the under-utilization of narrative messaging.

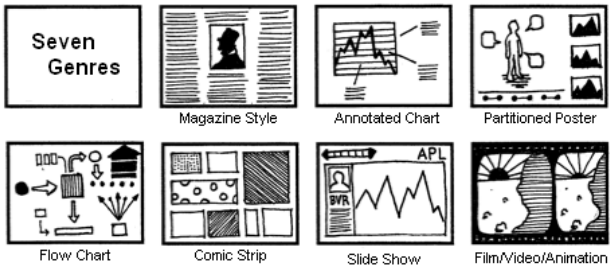


Fig. 8. Genres of Narrative Visualization.

The first pattern can be observed by the clusters of dark blue in the ordering section, suggesting clear differences between how visualizations guide the viewer through their content (Figure 7(1)). These clusters correspond to narrative formats such as slide shows, comic strips, annotated graphs, and others. We use these ordering types to identify distinct genres of visual narratives in Section 4.3.

The second pattern highlights the consistency in interaction design choices made by visualizations. Across the examples, we see the same interactive techniques being used (Figure 7(2)): hover highlighting and details-on-demand, limited interactivity, explicit instruction for interactive functionality, and navigation buttons when the visualization contains more than one frame (e.g., slideshows). The table also shows the consistent under-utilization of "tacit tutorials" and "stimulating default views" (Figure 7(3)). Tacit tutorials introduce a visualization's interactive functionality by animating the interactive components along with the presentation to make it clear how to manipulate the display. As a result, the user becomes familiar with the interactive capabilities of the visualization without requiring explicit instructions. Stimulating default views provide initial presentations of data and analysis intended to excite the user, a device analogous to journalistic leads. These views can then be used as jumping off points for further exploration. Both these techniques can be seamlessly incorporated into the visualization's design while simultaneously engaging the user in the interactive functionality.

The third pattern shows the under-utilization of common narrative messaging techniques such as repetition of key points, introductory texts, and final summaries and syntheses (Figure 7(4)). In particular, the data shows that interactive graphs do not include sufficient commentary for narrative purposes, with little use of repetition, multimessaging (i.e., text, images, and audio working together), or annotations to emphasize key observations from the data. Note that narrative messaging techniques are more frequently used in Slideshows and Videos, as these genres put more effort into communicating the narrative intended by the author. This may explain why qualitatively these visualizations feel more like "stories" and less like data tools.

4.3 Genres of Narrative Visualization

We found that our examples can be characterized by the 7 basic *genres* shown in Figure 8: magazine style, annotated chart, partitioned poster, flow chart, comic strip, slide show, and film/video/animation. These genres vary primarily in terms of (a) the number of frames—distinct visual scenes, multiplexed in time and/or space—that each contains, and (b) the ordering of their visual elements. For example, an image embedded in a page of text ("magazine style") has only a single frame, while a comic may have many frames. A multi-view visualization ("partitioned poster") may suggest only a loose order to its images, while a comic strip tends to follow a strict linear path.

These genres are not mutually exclusive: they can function like building blocks, combining to produce more complex visual genres. The Barry Bonds visualization (§3.1) is part Partitioned Poster and part Flow Chart, presenting multiple images simultaneously while using Flow Chart tactics to suggest a path to the viewer. Both the Budget Forecast (§3.2) and the Gapminder (§3.4) examples use Annotated Graphs but within a Slide Show format.

Though each of these genres can be used to tell a story, we note that different genres work better for different story types. Choosing the appropriate genre depends on a variety of factors, including the

Table 1. Properties of Author-Driven and Reader-Driven Stories. Most visualizations lie along a spectrum between these two extremes.

Author-Driven	Reader-Driven
Linear ordering of scenes	No prescribed ordering
Heavy messaging	No messaging
No interactivity	Free interactivity

complexity of the data, the complexity of the story, the intended audience, and the intended medium. There are clear cases in which a genre is more appropriate for a particular purpose. Business presentations typically use Slide Shows instead of Comic Strips, and television commercials use Videos instead of Flow Charts. These are common and intuitive cases, but not all instances are so clear cut. For example, it is not obvious whether students might learn best from a Slide Show or a Video or even a Comic Strip. The right choice also depends on the content being presented and the students' background. In general, there will be no "right answer" *a priori*, but several possible candidates, each with advantages and disadvantages.

Both messaging and interactivity can be layered on top of these genres. Messaging is the use of text to provide observations and explanations about the images. Typically this text takes familiar forms such as headlines, captions, labels, and annotations. For some visualizations, messaging can also include audio. Note that messaging is optional for any of the genres above, and can vary widely between instances of the same genre. Interactivity allows the visualization to be manipulated by the viewer. There are many possible types and degrees of interactivity, though common forms in narrative visualization include navigation buttons, hover highlighting, hover details-on-demand, filtering, searching, drill-down, zooming, and time sliders. Importantly, the appropriate use of messaging and interactivity will depend on a variety of factors. Messaging might clarify visual elements but produce clutter. Interactivity might engage the user but detract from the author's intended message. Again, these tradeoffs require context-specific consideration and judgment.

4.4 Balancing Author-Driven and Reader-Driven Stories

The visual narrative genres, together with interaction and messaging, must balance a narrative intended by the author with story discovery on the part of the reader. We thus place narrative visualizations along a spectrum of **author-driven** and **reader-driven** approaches (Table 1).

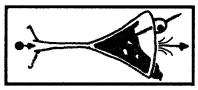
A purely author-driven approach has a strict linear path through the visualization, relies heavily on messaging, and includes no interactivity. Examples include film and non-interactive slideshows. A strongly author-driven approach works best when the goal is storytelling or efficient communication. We see this approach used in comics, art, cinema, commercials, business presentations, educational videos, and training materials.

A purely reader-driven approach has no prescribed ordering of images, no messaging, and a high degree of interactivity. Examples include visual analysis tools like Tableau or Spotfire. A reader-driven approach supports tasks such as data diagnostics, pattern discovery, and hypothesis formation.

Historically, many visualizations fall into the author-driven or reader-driven dichotomy. However, as we have seen throughout our case studies, most examples of narrative visualization fall somewhere in-between, and an important attribute of narrative visualization is its flexibility in balancing both elements. Visualizations are increasingly striking a balance between the two approaches, providing room for limited interactivity within the context of a more structured narrative. This is a relatively recent development, with most mainstream examples coming from online journalism.

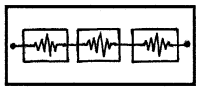
All the interactive examples in our dataset use a mix of the author-driven and reader-driven approaches. Despite the range of possible combinations, a few hybrid models have become most common. Below we discuss three common schemas. The first structure prioritizes the author-driven approach, the second structure promotes a dialogue between the two approaches, while the third structure prioritizes the reader-driven approach.

4.4.1 Martini Glass Structure



The Martini Glass visualization structure begins with an author-driven approach, initially using questions, observations, or written articles to introduce the visualization. Occasionally no text is used at all, as the visualization instead relies on an interesting default view or annotations. Once the author's intended narrative is complete, the visualization opens up to a reader-driven stage where the user is free to interactively explore the data. The structure resembles a martini glass, with the stem representing the single-path author-driven narrative and the widening mouth of the glass representing the available paths made possible through reader-driven interactivity. Using this image, we can think of varying degrees of authoring (question, observation, article) as corresponding to different stem types (short, long), and varying degrees of readership (highlighting, filtering, path-choosing) corresponding to different mouth shapes. With all these permutations, the general structure remains intact, with the author-driven narrative functioning first, then followed separately by the reader-driven interactions. The authoring segment may function as a jumping off point for the reader's interaction, with questions, observations, and themes suggesting the types of issues a reader might explore on his own. This structure is the most common across the interactive visualizations we examined.

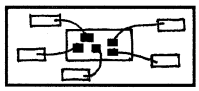
4.4.2 Interactive Slideshow



The Interactive Slideshow structure follows a typical slideshow format, but incorporates interaction mid-narrative within the confines of each slide. This structure allows the user to further explore particular points of the presentation before moving ahead to the next stage of the story. We saw this structure in both the Budget Forecasts (§3.2) and Gapminder (§3.4) case studies. Contrary to the martini glass, an interactive slideshow allows for interaction mid-narrative, a more balanced mix of author-driven and reader-driven approaches. However, individual slides often function in the martini glass style, again communicating author-intended messages prior to prompting the user to interact with the display.

Interactive slideshows work well with both complex datasets and narratives. For complex datasets, this structure allows the author to walk the user through data-dimensions and manipulations step-by-step. This ensures that the user only moves forward in the presentation when he is ready to do so, and allows the user to repeat steps if desired. For complex narratives, this format allows the author to draw discrete boundaries between different story segments, similar to a cut in film.

4.4.3 Drill-Down Story



The Drill-Down Story visualization structure presents a general theme and then allows the user to choose among particular instances of that theme to reveal additional details and backstories. For instance, the theme might be "Historical Bear Markets" [A31] and the visualization will allow the user to drill-down to a particular bear market to learn more about its history. Or a map showing "North Korean Prison Camps" [A38] may allow the user to learn more about individual camps by clicking on a specific location on the map. This structure puts more emphasis on the reader-driven approach, letting the user dictate what stories are told and when. Nevertheless, it still requires significant amounts of authoring to determine the possible types of user interaction, what candidate stories to include, and the details included for each story.

5 Discussion

In this paper, we conducted a design space analysis of narrative visualization—visualizations intended to convey stories—based on a corpus of 58 collected examples from online journalism, graphic design, comics, business, art, and visualization research. Our analysis highlights visual and interactive devices that support storytelling with data, and we identify distinct genres of visualization using narrative structures such as the martini glass, interactive slideshow, and drill-down story. In particular, we note a central concern in the design of narrative visualizations: the balance between author-driven

elements—providing narrative structure and messaging—and reader-driven elements—enabling interactive exploration and social sharing. These results help identify successful design practices. By explicitly naming effective techniques (e.g., "tacit tutorials", "semantic consistency", "matching on content") we hope to facilitate their reuse.

Narrative visualizations differ in important ways from traditional forms of storytelling. In journalism, one presents related material and sources together in a "block progression" to have clear and logical transitions, and digresses "often, but not for long" [2]. Interactive stories present difficulties for these recommendations, as giving narrative control to the reader permits lengthy unordered digressions. The design structures we identify help counter these pitfalls. Generalizing across our examples, data stories appear to be most effective when they have constrained interaction at various checkpoints within a narrative, allowing the user to explore the data without veering too far from the intended narrative. That said, further exploration of transitions between author- and reader-driven elements presents an exciting area for researchers and practitioners.

Our analysis also helps identify under-explored regions of the design space. For example, the "magazine style" genre is the most common genre for static visualizations, but has not been as richly utilized with interactive visualizations. How might multiple media be better integrated for storytelling? For example, a martini glass structure for a visualization may be weaved into a text story: static images might first support the text and introduce the visualization; an embedded interactive visualization may appear later, perhaps with links in the text setting visualization parameters to highlight points made within the prose; finally, at the article's end, the visualization may open up to enable free exploration. Likewise, our data shows that interactivity is not yet common in flowcharts, comics, or videos, and that few visualizations currently use tacit tutorials or stimulating default views. In this manner, our framework facilitates reasoning about novel juxtapositions of genres and narrative devices.

As our understanding of narrative visualization improves, it also opens up new opportunities for visualization tool research. How should we extend visual analysis applications to enable storytelling? Interfaces that combine visualization construction with the specification of narrative structure, textual/graphical annotation, visual highlighting techniques, transitions, and interactive controls could have a transformative impact on the medium, so long as they can be used by data domain experts, not just technology experts. We believe that our results identify important features for these future tools. By identifying recurring design patterns, we hope to help catalyze novel tools and explorations of narrative visualization.

However, we must acknowledge that we are not experts in the study of narrative. Rather, we are visualization designers and technologists seeking to better understand the potential of the medium. Inevitably, there is much that remains to be understood. For instance, what mix of author-driven and reader-driven elements is best for different purposes? How does this vary based on the data at hand, the desired story form, and the audience? How critical is it to provide either explicit instruction or tacit tutorials to introduce interactive features? Will these elements become less necessary as viewers become more accustomed to narrative visualization? The topic is ripe for future work, and would further benefit from the input of artists, educators, and journalists.

By investigating the narrative devices used in a corpus of visualizations, our analysis has focused primarily on the design decisions made by visualization creators. A promising direction for future research is to focus squarely on readers' experiences when viewing and interacting with narrative visualizations. Eye-tracking studies of newspaper reading [11, 16] have found that readers regularly skim by scanning graphics, headlines, and initial paragraphs before intermittently stopping to read an article. Based on these results, Garcia & Stark [11] define newspaper design as the challenge *"to give readers material that is worthy of their scan, that makes them stop scanning and start reading."* How do such behaviors apply to visualization? Further research is needed to characterize how readers perceive narratives presented via visualizations. Such studies could provide insights for design, such as how viewers might best "skim" a narrative visualization.

A related topic is reader engagement. The examples we analyzed tended to have "hard leads"—brief summaries describing the content of the visualization—whereas journalism often adopts more mysterious leads [2] to promote engagement. How can "stimulating default views" for visualizations best capture readers' attention and personally engage them in the world of the narrative? Moreover, narrative visualizations put data at the forefront of storytelling, yet others [2, 7] have noted that a myopic focus on data may be a stumbling block to narrative flow and reader engagement. The strategies discussed above suggest ways to incorporate statistics in concert with narrative, potentially enhancing readers' engagement with data. As Blundell [2] notes, *"We're supposed to be tellers of tales as well as purveyors of facts. When we don't live up to that responsibility we don't get read."*

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APPENDIX: NARRATIVE VISUALIZATION EXAMPLES

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