The Visual Rhetoric of Data Displays: The Conundrum of Clarity

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Abstract—*The visual rhetoric of data displays (e.g., charts, graphs, maps) has changed profoundly over the past 50 years as a result of research in display techniques, the application of traditional and emerging rhetorical approaches, and the democratizing effects of data design technology. Perhaps in no other visual realm than data design is the notion of clarity more critical or more contested. Indeed the ascendancy of rhetorical approaches was initiated by the perceptual/cognitive science of data design, which in seeking to identify optimal display techniques, fostered a concern for ethics and evoked the universality and minimalism of modernist aesthetics. The rhetoric of adaptation, which emphasizes the variability of audiences, purposes, and situational contexts, rendered clarity contingent and mutable—a moving target that requires constant attention. Social rhetoric considered data design as a collective construct, tethering clarity to visual discourse communities, convention-building, cultural values, and power. The concept of clarity has been further reoriented by the rhetoric of participation, which is fostered by interactive digital design that enables users to adapt displays according to their needs and interests.*

Index Terms—*Data displays, graphics, information design, information visualization, visual rhetoric.*

Charts and graphs appear today nearly everywhere—technical reports, research articles, and annual reports as well as less formal documents such as fact sheets, brochures, newsletters, and even monthly power bills. And as the internet has grown, the ubiquity of data displays online has vastly accelerated. Now, in the first decade of the 21st century, consumers of information are immersed in data visualization. Advances in the technology used to create and display charts, which are increasingly interactive and on a screen rather than on static paper, ensure that this trend will only continue. We are already inundated with data displays, and a deluge is heading our way.

In order to glimpse that future, I will outline several approaches to the visual rhetoric of data design over the past half century, using clarity as a touchstone by which to compare and contrast these approaches. Because data displays are quintessentially utilitarian in nature, the rhetoric of data displays begins with the issue of clarity and the injunction that they must facilitate the reader's **comprehension of the data**. We are immediately drawn to Tufte's maxim that "[g]raphical excellence consists of complex ideas communicated with clarity, precision, and efficiency," that it "gives to the viewer the greatest number of ideas in the shortest time with the least ink in the smallest space" and that it "requires telling the truth about the data" [1, p. 51]. Who would dare contest such timeless, universal, and self-evident maxims that coalesce around the gold standard of data design—clarity? What reader would expect anything less?

However, from the standpoint of readers who individually and collectively interpret the billions of data displays produced annually—and especially now in an environment of fast-moving technology with a global reach—how exactly do we define clarity? When viewed through the reader-oriented lens of rhetoric, and through the multiple lenses of several rhetorical approaches that have evolved over the past 50 years, the concept of clarity can be multifaceted, complex, and even contradictory—in short, something of a conundrum.

To define and explore that conundrum, I begin with the rhetoric of science, which is built on perceptual/cognitive models and empirical research. Although the advocates of this approach are not rhetoricians per se, how they conceptualize readers certainly has rhetorical implications. Next, I examine clarity through two other lenses: the rhetoric of adaptation, which extends the rhetorical tradition of tailoring communications to specific situations and where clarity is contingent on audience, purpose, and context; and social rhetoric, which views data design as a process of communal convention-building whereby readers interpret displays through their collective learning, experience, and values. I then examine the emergence of digital data design and the rhetoric of participation, in which readers actively manipulate displays, digging beneath the surface and exploring and exploiting them according to

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their own interests and interpretive preferences. Although I discuss these four approaches in the rough sequence in which they have developed, they all have their advocates today. Moreover, the rhetorical approaches are not absolutely distinct from each other by any means, and so they cannot be discussed in total isolation. And although data design is a rhetorical process between designer and reader, I focus primarily on the reader's perspective.

Along the way, I assess the profound impact of technology on visual rhetoric, both in terms of interpreting computer-generated print displays and interacting with them online. Technology has always played a role in data visualization, and over the past two decades it has revolutionized its design, production, and reception—particularly the emerging technology of digital data display. The rhetoric of data design technology parallels the rhetoric of new media, which has both "centripetal" and "centrifugal" aspects, whereby it pulls to the center certain conventional practices while at the same time it spins outward as both designers and users chart their own ways [2, pp. 331–332].

THE RHETORIC OF SCIENCE: THE NEXUS OF SCIENCE, PERCEPTION, AND AESTHETICS

For some time, particularly in the field of statistics, researchers have studied the perceptual effects of data displays in an attempt to identify the most effective practices—in other words, displays that exemplify **clarity**. The rhetoric of clarity is rooted in what Brasseur calls the "perceptual cognitive-based school of thought" [3, p. 4]), the rational, research-intensive approach that she claims dominates the field of data design [3]. The objective of this approach is to identify principles of design that will ensure the optimal transmission of data from designer to user. In static print displays, this approach extends the so-called "transmission" model of communication pioneered by Shannon and Weaver [4]. A belief in the shared rational thinking of users is its creed, and nature and science are its guides.

The cognitive perceptual school derives its principles from empirical research into effective data display, which goes back far longer than 50 years, as MacDonald-Ross documents it [5], and is exemplified in the information-processing models of Bertin [6] and the research of Cleveland and McGill [7], who studied graphical forms based on perceptual and cognitive criteria. Empirical research like Cleveland and McGill's sought to address the question of which display techniques

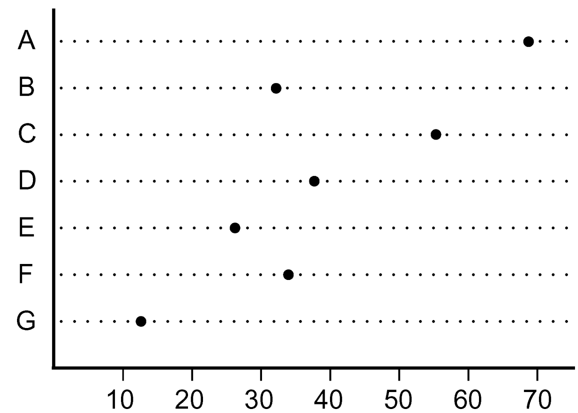


Fig. 1. Simple example of the efficient dot chart advocated by Cleveland [7], [9].

(e.g., area, lines, grayscales, color) enable optimal interpretation (i.e., those that engender the greatest clarity). For example, according to Cleveland and McGill's research, readers can compare data on bar graphs better than on pie charts because bar charts adhere more closely to the optimal configuration: "Position along a common scale" [7, p. 536]. Areas, volumes, and grayscales, on the other hand, yield less accurate results for readers (see also Cochran, Albrecht, and Green [8]). Cleveland's famous "dot chart," which is illustrated in Fig. 1, applies this research by adhering strictly to the "position along a common scale" principle [7, pp. 545, 547–548], [9, pp. 12–15, 34, 302–340].

This approach to data visualization finds its intellectual roots in the work of Neurath [10], who in the early 20th century invented his Isotype pictographic displays, a system that was founded on philosophical positivism and gestalt principles of perception and that was intended to make statistical data accessible to a wide public audience [11]. This rational, scientific approach is exemplified by many recent scholars and practitioners in the field, chief among them Bertin, whose semiotic model of data display is based on cognitive and perceptual principles of "information processing" [6, pp. 180–184] (see also [12]). In the area of computer-generated and online data design, both Spence's *Information Visualization* [13] and Card, Mackinlay, and Shneiderman's *Readings in Information Visualization* [14] (a collection of papers on cutting-edge concepts and techniques) have a cognitive-perceptual orientation. Although Tufte's design philosophy is too complex to be easily categorized, he also largely advocates this approach [3], given his emphasis on universal principles of design and his ideal of having data displays emulate nature [15].

One could argue that this rational, cognitive-perceptual approach is essentially non-rhetorical because it assumes that readers are universal—that they are largely undifferentiated from each other and share a common interpretive framework, in that their brains are hard-wired to process some design elements better than others. Ideally, however, the tight and abiding focus on audience of this approach yields rhetorical benefits—mainly, the efficiency and predictability of readers' responses. Researchers can identify forms with optimal clarity, and designers can apply these findings by calculating the interpretive gain or loss in deploying certain forms. Readers are well served because their visual processing is maximized, they consequently have a high degree of confidence in the data, and they are spared perceptual disasters. This rhetoric of clarity with its emphasis on the rational efficiency of language finds its modern antecedent in the 17th-century rhetoric of the Royal Society of London, which eschewed verbal embellishments that impeded the transmission of fact and truth. And indeed experimental graphs that appeared in the early *Philosophical Transactions of the Royal Society* modeled this standard visually [16].

This rational, efficient rhetoric of data design embodies an intrinsic ethical component because it implies that readers deserve a full, unadulterated disclosure of the data and that designers have a moral imperative to provide it. This imperative was illustrated at least as early as 1914 by Brinton's *Graphic Methods for Presenting Facts* [17], in which he exposed deceptive practices of displaying data by explaining the underlying flaws and how readers could identify them to avoid being hoodwinked. The moral imperative of clarity culminated in the early 1950s with Huff and Geis's classic *How to Lie with Statistics* [18], which demonstrated how designers, unconstrained by graphical standards or professional oversight, can manipulate charts and graphs for their own ends. Caveat rhetor: Unwitting readers need to protect themselves from these practices and arm themselves with the interpretive tools to unmask deceptive data design.

Tufte extends this tradition by aiming to protect visual consumers from deceptive and abominable design practices, which are particularly prevalent in the popular media. Beginning with *The Visual Display of Quantitative Information* over two decades ago, Tufte has emerged as one of the prominent figures in contemporary data design and his influence spans many disciplines. For Tufte, "telling the truth about the data" [1, p. 51] requires the designer to avoid the "Lie Factor" [1, p. 57], whereby the size of the data fails to match its visual representation. In addition, credible displays should be structurally transparent, avoid clutter (what Tufte calls "chartjunk" [1, p. 107]), and be visually concise (Tufte's "Data-ink ratio" and "data density" [1, pp. 93, 162]). All of these prescriptions ensure that readers are protected from the excesses, malpractice, and duplicity of designers.

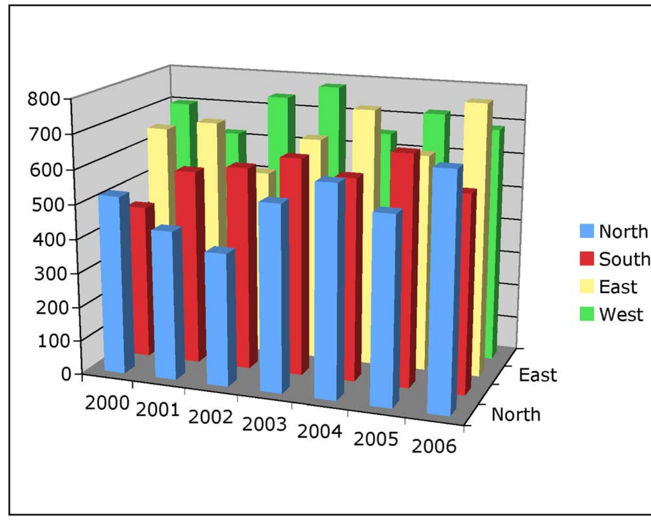


Fig. 2. Perceptual and ethos problems with graphing software.

This heightened vigilance about ethical issues in data visualization is highly warranted, largely because data can be visualized in so many different forms, like the shifting sands on a beach. The design templates and wizards of graphing software make readers particularly vulnerable. Three-dimensional displays often hide data or impede the reader's ability to make comparisons; pie, donut, and mountain charts require readers to compare oddly shaped areas; and options for filling bars, plot frames, and other forms can result in eye-straining clashes of colors and patterns. By undermining the clarity of the display, these perceptual faux pas also weaken the ethos, or credibility, of the designer. Readers may wonder, for instance, why the designer is hiding data in a forest of bars in the 3-D multiple bar chart shown in Fig. 2. What the designer probably intended as a way to bolster ethos—visualizing the data in the seemingly more complex, sophisticated, and labor-intensive realm of perspective—may very well have the opposite rhetorical effect, with the perceptual challenge undermining ethos by degrading clarity.

The rhetoric of science also embodies an aesthetic element that both belies and complements its rationalism. Brasseur claims members of the "graphing culture," particularly mathematicians, often celebrate the aesthetics of data design [3, pp. 27–28]. Although he derides graphics that foreground the artistic element, Tufte the social scientist waxes aesthetic about the "wonder," "beauty," and "graphical elegance" of well-designed displays [1, pp. 121, 137, 177]. By eliciting a subjective response from readers, this ancillary aesthetic element engenders two rhetorical effects. First, it makes displays more inviting to readers because readers are naturally drawn to elegant displays; and second, it bolsters their credibility because beauty and truth are cognate qualities.

The rhetoric of science also embodies a broader and more pervasive aesthetic element that closely dovetails with 20th-century modernism. Modernists advocated minimalist, high-contrast displays guided by perceptual principles—particularly gestalt principles—so that they could appeal to large public audiences, often across cultures and national borders, as exemplified by Neurath's Isotype [10]. Modernists emphasized direct, unmediated communication that was objective, perceptually pure, and unburdened by past conventions, resulting in what Kinross calls the "rhetoric of neutrality"—an attempt to trump rhetoric but which itself engendered a rhetorical stance [19, pp. 22–29]. With its emphasis on objective, universal, and culturally neutral design, modernism complements and indeed fosters the rhetoric of science.

So if we examine the display in Fig. 3 through the lens of the rhetoric of science, several questions come to the fore about its **clarity**. Does the display enable optimal perceptual uptake of the data? The high figure-ground contrast of the bars, the display of data points "along a common scale," and the gridlines will all help here. Is the display lean and efficient? Bars are less so than lines or dots, but they are at least thin, and they don't contain distracting color or patterns. Does it "tell the truth" about the data? The X-axis begins at zero, and the plot frame does not stretch inordinately in either direction, so it probably meets this criterion. Is it elegant? Its lack of complexity and sophistication probably prevent it from rising to that level, but its stoic simplicity might be pleasing, if not inviting, to readers.

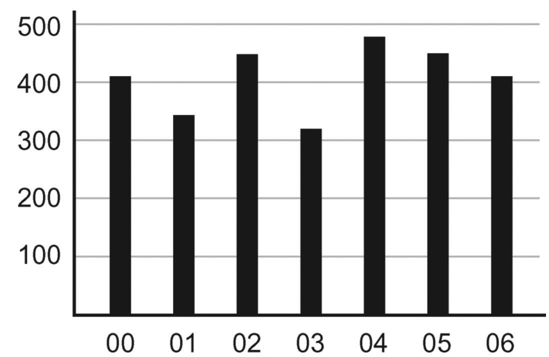


Fig. 3. Sample bar chart.

Rhetorical Adaptation: Contingencies of Data Visualization

Clarity and ethos, however, can be contingent and even elusive when data displays are interpreted, as they always are, in specific rhetorical situations; that is, they are interpreted relative to the audiences for the display, its purposes, and the contexts in which readers encounter it [20], [21]. While the rhetoric of science aspires to a Platonic-like, universal ideal that supersedes time and place, the rhetoric of adaptation finds it roots largely in traditional rhetoric and hinges on the opportunities and constraints of communicative interactions. Although the philosophy of rhetorical adaptation is now common in the field of professional communication, and increasingly so in graphic design, it is still relatively foreign to science and social science fields like statistics and economics, which rely heavily on data design.

That the rhetoric of adaptation remains obscure in many disciplines is not surprising, given its variable and relativistic nature, which eludes scientific description and lacks certainty. For one, the rhetoric of adaptation accepts—even celebrates—that different readers have different interpretive frameworks that profoundly influence what they find clear and credible in data displays. A highly technical chart that appears in a journal for high-energy physicists may be perfectly **clear** to that audience, but that same chart may be inscrutable to lay readers. A simple, low-key display (like the one in Fig. 3) that readers are highly motivated to explore may engage them quite successfully, but for indifferent readers, clarity may be irrelevant if the display fails to capture their attention. As shown in Fig. 4, the display may need more energy—lightly shaded bars against a rich pattern in the plot frame—to spark the reader's interest. If that version is still too low key for the rhetorical situation, the designer may even have to

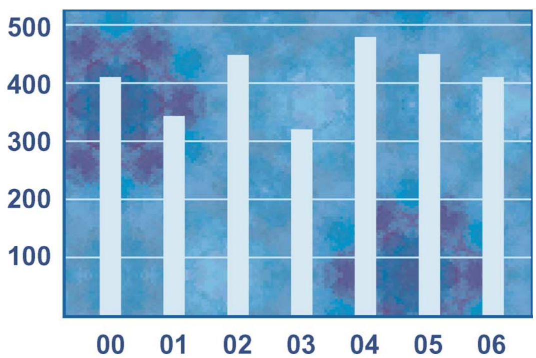


Fig. 4. Sample bar chart revised to stimulate interest.

resort to some of Tufte's loathsome "chartjunk." In these ways, clarity may initially depend on pathos appeals that draw readers into the display by stirring their emotions.

The purpose of a display also plays a major role in determining its clarity. A simple and perceptually transparent line graph with financial data may fail in its purpose if managers of a company rely on it to make decisions. Clarity in this situation may require more design—for example, gridlines, a larger plot frame, and data labels—for readers to obtain a sufficiently precise interpretation. On the other hand, readers of the company's annual report who use the display to make investment decisions may need to see only the macro-level trends and patterns, and for these readers the streamlined version will best achieve its purpose. So depending on the purpose of the display, its embellishments may hinder, rather than enhance, clarity.

The physical, perceptual, and historical context in which the display is read will also affect the reader's interpretation of the data. Depending on the immediate environment in which the display appears—in a board room presentation, buried in a report, or online—readers may have different perceptual and interpretive experiences, ranging from challenging (back row of the board room, a busy office space, screen glare) or ideal (front row, a private office, optimal lighting). That interpretation also depends on KAIROS: the circumstances of the moment relative to a particular time and place. A map displaying polling data about political candidates may be compelling to readers in an election year with close races but far less so most other times. Currently, an Iraq map displaying war data has great kairos, partly because of the intense arguments about what to do next; indeed, the display itself may argue for a certain course of action. However, a century from now when the witnesses to the Iraq war have long since passed, its interpretation will change, just as time has altered our interpretation of Minard's famous chart of Napolean's Russian campaign [1, p. 41].

In short, the clarity of a data display depends on its fit for a given rhetorical situation. A good match for one rhetorical situation may be a disaster in another, and vice versa. Of course, however skillful and well-intentioned a designer may be about analyzing a rhetorical situation and adapting displays to it, the match with a given situation can remain at risk, especially without direct feedback from the audience. By studying design in context and by eliciting holistic feedback directly from readers, designers can interrogate the clarity of a display for a given rhetorical situation using context-specific research which entails a variety of methods—testing, interviews, questionnaires, observations, focus groups, and the like [20]. Schriver, for example, extends rhetorical analysis to action by envisioning design as an iterative, interactive process of radical audience adaptation, whereby designers constantly solicit, analyze, and implement reader feedback [22].

The opportunities for implementing rhetorical adaptation have increased exponentially over the past 15 years by the widespread access to computer-generated graphics. In the history of data design over the past 350 years, no tool has more profoundly revolutionized data visualization by drastically reducing the labor to create and modify charts and graphs. A decade and a half ago, virtually anyone who had the skill to **interpret** data displays was suddenly empowered to **design** them as well, thus democratizing data design in the same way that laser printers democratized text design. In doing so, computer-generated displays initiated a critical shift in the rhetorical process by substantially altering reader expectations. Given the templates and wizards at their fingertips, professional communicators are now expected to visualize data, and because the technology offers the opportunity for rhetorical adaptation, readers expect that designers will seize that opportunity. To the extent that designers do, a well-executed display will enhance its clarity **and** its ethos, as readers recognize the designer's ability to manipulate the technology for the reader's benefit.

The effects of these technological tools, however, have been mixed, partly because not every professional communicator has the skills or motivation to master them, and partly because the defaults, templates, and wizards can actually undermine, rather than foster, rhetorical adaptation by impeding the designer's inclination to consider optimal design solutions, as Brasseur shows in her study of fill patterns [23]. The array of design options in software like Microsoft Excel and PowerPoint creates the **illusion** of flexibility. With a few clicks, virtually any designer can completely transform the appearance of a graph—for example, by altering its genre, adding 3-D effects and colorful bars, and stretching the plot frame or filling it with a gradient texture. So marvelously malleable are these graphical effects—but for whom and to what end? Paradoxically, then, even as the technology for visualizing data has become more sophisticated, it does not necessarily engender rhetorically sensitive design. However, as we will see with the participatory rhetoric of digital data design, that dynamic will be redefined because adaptation is controlled partially by the readers themselves.

Social Rhetoric: What Readers Bring to the Interpretive Act

Clarity may lie in the eye of the beholder, as the rhetoric of adaptation tells us, but oftentimes it lies simultaneously in the eyes of many beholders. Because data design occurs in a particular historical and cultural context shared by large numbers of readers, its interpretation is a highly social act. Given that data design is very conventional and that readers learn how to interpret displays (and often different genres of displays) in a variety of ways, the social approach finds problematic the assumption that the reader's perceptual system or situational variables dominate interpretation. Simply put, from the perspective of social rhetoric, **nature** may play a role in interpretation, but **nurture** really matters.

Examining data displays through the lens of social rhetoric complicates how designers deploy and readers interpret displays. Clarity remains an issue, but how it is achieved in the minds of readers becomes murkier, more variegated, and less visible. Analyzing a rhetorical situation tells us a great deal about what's explicit and idiosyncratic about the interaction between designer and reader, but the outcome of that interaction also relies on what lies beneath the surface, what knowledge readers implicitly share that they bring to that interaction. From a social perspective, clarity depends on a process of learning and enculturation, and that perspective is particularly relevant to data displays, given that they are intrinsically artificial and conventional.

We are not born with the capacity to read charts and graphs, so we acquire this skill, to varying degrees, depending on the visual discourse communities we participate in, including those communities that coalesce around organizations, disciplines, and more broadly, nations and cultures [16]. Disciplinary knowledge is typically acquired through formal training. For example, sociologists learn how to read scatterplots and population distribution charts, economists learn how to read candle-stick graphs, geologists learn how to read topographical maps, nurses and doctors learn how to read cardiograms, and so on. Drawing on the work of sociologists such as LaTour and Woolgar, Brasseur observes that the data displays used by scientists are shaped by the collective social processes in which these forms originate [3]. The interpretive skills of members of a given discipline can be highly specialized and sophisticated—for example, a geologist who reads seismic diagrams to locate or predict an earthquake or a structural engineer who reads graphs about the strength of building materials to determine their suitability for various applications.

Organizations may also develop their own methods of data visualization (e.g., charts or diagrams displaying hourly energy use), or they may adapt existing forms to meet their own needs (e.g., line graphs with a consistent design in monthly production reports). In these ways, organizations provide a reliable framework for their members to interpret data, and clarity is enabled, or at least greatly enhanced, as members become accustomed to these practices.

So if we regard data displays as socially constructed conventions, clarity depends on readers' experiences in disciplines and organizations but also as members of **public** discourse communities that enculturate readers in forms of data visualization through schools, popular culture, and news media. As a result, visual literacy varies across national boundaries (Tufte, for example, claims that displays are more complex in Japan than in the US [1, pp. 82–84]). The effects of a collective, national experience on visual literacy are illustrated by the series of statistical atlases of the United States, which first appeared in 1874 [24]. The atlases contained hundreds of displays of census data in a variety of forms, such as pie charts, population distribution charts, bar charts, percent charts, and many others. So novel were most of these forms to the public that the early atlases provided detailed explanations on how to interpret them; however, as Americans collectively

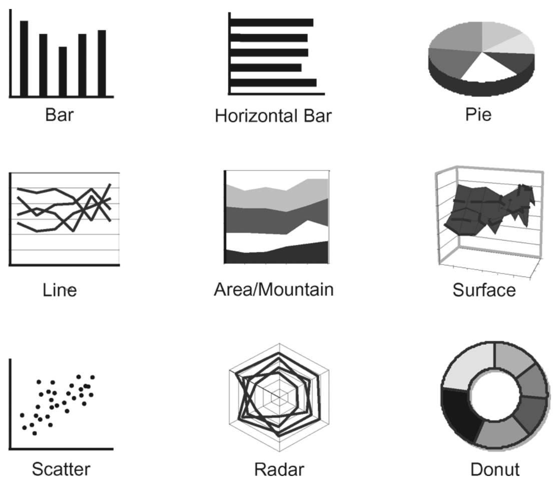


Fig. 5. Genres included in typical graphing software.

became accustomed to reading data displays, the explanations disappeared in later editions because the public had achieved a level of visual literacy that rendered the explanations unnecessary [25].

Technology has also influenced the social aspects of visual rhetoric. Popular data design software, like Microsoft Excel and PowerPoint, reproduces and reifies a small set of conventional genres, as shown in Fig. 5. Circumscribing the designer's available design choices helps enculturate readers into a finite group of familiar forms and thereby reduces the reader's interpretive stress. In this way, data design software both enhances and constrains visual literacy, ensuring that a wide range of readers become enculturated in certain conventional genres—from scatterplots to donut charts—while at the same time limiting data visualization to those forms. Of course, popular graphing software also has the rhetorical drawbacks of suppressing less well-known conventions and inhibiting the invention of new ones.

Interpreting data displays can also be filtered by the reader's cultural background, though this factor might be less influential than for other forms of visual communication such as illustrations, symbols, or icons. Nevertheless, a color scheme for bars on a chart—say red and blue—might mean something quite different to an American reader than to a Chinese reader. A newspaper display with pictorial elements—say a line graph about oil inscribed in a 10-gallon Texas hat—might produce a similar interpretive divergence between American readers and Saudi readers. Cultural knowledge also includes aesthetics. Modernism profoundly affected the way we look at any designed artifact, including data displays. Fig. 3 certainly invokes the lean, efficient, high-contrast aesthetic of modernism, which for many contemporary readers may bolster its ethos; to other readers, however, its stark nakedness may make it look dated and passé.

The social aspect of conventions is further illuminated by theorists like Barton and Barton, who scrutinize the purposes data displays fulfill through the power that they embody [26], [27]. That power can be measured in part by whose interest those displays serve, how designers control what information they include or exclude in a display, and the "naturalizing" effect displays create when readers interpret them uncritically rather than as artificial constructs [27]. In these ways, readers collectively delegate power to data displays that may serve their own self-interests (e.g., by perpetuating the status quo), or they might unwittingly cede their own power by acquiescing to forms that they lack the pragmatic, intellectual, or cultural authority to resist.

Because readers' encounters with data displays do not occur in a social or cultural vacuum, achieving clarity is a collective, though often invisible, effort. Readers are not naïve noble savages who gaze innocently; rather, they are members of discourse communities—large and small, public and specialized—that foster their interpretive skills. So when readers encounter a display, they bring with them experiences and expectations that define their sense of clarity.

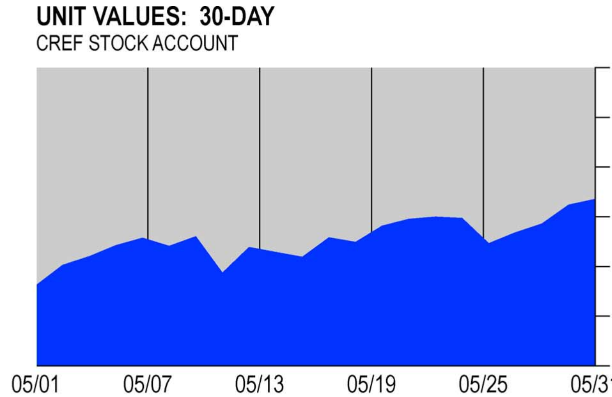
The Rhetoric of Participation: The Postmodern Frontier of Dynamic Displays

Visual rhetoric is being transformed by another wave of technological advances that has occurred with the proliferation of the World Wide Web. Digital data design, whereby the display is produced and interpreted entirely on a screen (and typically on the web), has opened up opportunities to invent novel designs and to widen the pool of conventional forms, including some from the past, and thereby socialize design by redefining our concept of visual literacy. Because many digital online displays are interactive, they allow readers (or **users**, given their redefined role) to adapt them to their varying needs and interests, fulfilling traditional rhetorical goals. Zappen claims that digital media, broadly construed, is transforming rhetoric through "self-expression, participation, and creative collaboration" [28, p. 321]. Although self-expression and creative collaboration are facets of the emerging rhetoric of digital data visualization, active reader participation stands at the heart of this enterprise.

This shift from print to screen has enormous consequences for clarity because print limits the amount of data that can be visualized and reasonably processed in a single static display, whatever its genre. Interactive displays give readers access to complex data sets,[1] which enhance clarity through the close proximity of displays that would otherwise—in print form—be scattered across multiple surfaces. Interactive displays also enhance clarity by empowering readers to visualize data themselves by controlling the size, scope, and genre of the display. Conceptually, then, in the realm of interactive digital design, Fig. 3 is a mere surface chart that readers can metamorphose in a variety of ways, with a rich underlayer of possibilities waiting for the reader to discover.

Audience Adaptation Online data design shifts the user's interpretive act from a passive to an active, participatory role. Clarity becomes a moving, self-adjusting target whereby users shape (and reshape) data displays according to their needs and preferences. In static print displays, the burden is placed entirely on the designer to adapt the display to the rhetorical situation by choosing the data set for the display, the genre in which the data appear (bar chart, line graph, scatterplot, etc.), and the design features of the display. Print limits the amount of data that can be visualized and that users can reasonably process in a single display. With interactive displays, on the other hand, users **participate** in adapting the display, which empowers them to visualize data on their own terms and which places them in a quasi-collaborative relationship with the designer. Moreover, interactive displays give users access to complex data sets by allowing them to mine them for information they want to visualize. For example, investment performance charts typically allow users to display data in different time zones, enabling users to visualize both short- and long-term performance. The investment performance charts in the TIAA-CREF website, for example, allow users to display data in several time zones, ranging from 30 days (top of Fig. 6) to 10 years (bottom of Fig. 6) [29]. In this instance, each of these displays yields a very different picture of the "Stock" fund, enabling users to visualize both short- and long-term performance.

[1]I would like to acknowledge my colleague Heike Hofmann for this observation.



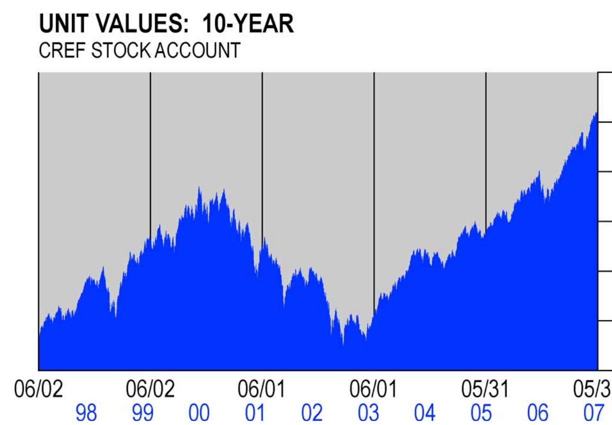


Fig. 6. Interactive display of 30-day and 10-year investment performance of the "Stock Fund" from the TIAA-CREF Website [29]. These charts show only daily unit values and do not present performance figures for any TIAA-CREF product. Reproduced with permission of TIAA-CREF.

Interactive displays with additional options can be found at the Bankrate.com website, where within the same plot frame users can graph interest rates for mortgages, both nationally and in a specific state of their choosing, as well as over several time spans [30]. Users can also choose the genre—line, scatter, area, or bar graph—so if one form of graph doesn't provide adequate clarity or perceptual efficiency or meet the reader's expectations, readers can transform the display into another genre, adapting the variables (e.g., time, place, genre of display) to their own informational needs and preferences. Unlike a static graph, readers can generate several views of the same data or, more importantly, mine and visualize more complex data sets by digging beneath the surface display.

Because they place users in a position of authority by giving them control over how data is visualized, interactive displays are highly postmodern in their rhetorical and aesthetic orientation. Interactive displays are multilayered and flexible, and they trump modernist assumptions about the authoritative relationship between designer and user. In interactive displays, meaning lies beneath the surface, waiting for the user to discover—unlike modernism which promoted authoritative transparency and designer control (epitomized by Neurath's high-contrast Isotype displays, where meaning was accessed explicitly on the surface). By contrast, the surface image of interactive displays belies its complexity, engendering a rhetoric of accessibility that enables readers to extract the information they need from complex data sets without being overwhelmed by them.

Visualizing Macro-/Micro-Levels Unlike a static graph, interactive displays enable users with different motivations and information needs to explore data at their own pace and level and, more importantly, mine and visualize complex data sets. By zooming in and out of the display, users can visualize what Tufte calls the "macro" and "micro" views [32, pp. 37–51]. Users of the TIAA-CREF and Bankrate.com charts have this flexibility by being able to select a spectrum of displays ranging from the micro to the macro view. Of course, interactivity does not guarantee rhetorical adaptability to every situation. The TIAA-CREF and Bankrate.com charts are not detailed and precise enough for readers to make fine-grained comparisons, which limits their rhetorical flexibility. Investors and mortgage shoppers will likely find them helpful for long-term decision-making, but users who need more micro-level precision, like day traders and lenders, probably will not.

An imaginative graphing system that gives users a high level of flexibility to explore the data on both the macro- and micro-levels is *NameVoyager*, which uses data from the US Government to display the popularity of the top 1,000 baby names by gender since the 1880s, primarily so that prospective parents can make informed name choices [33]. Scrolling over an area/mountain graph (Fig. 7) shows the top 1,000 names of boys (blue) and girls (pink), with the thickness of the area representing the number of children per million with a particular name in a given year. For example, the names John and Mary have always been popular names. On the micro-level, users can click on a specific name or enter a name at the top of the display to generate a separate graph for a particular name.

As shown in Fig. 8, the name Elizabeth was more popular in the past than the present, though it experienced a resurgence in the 1980s. Scrolling

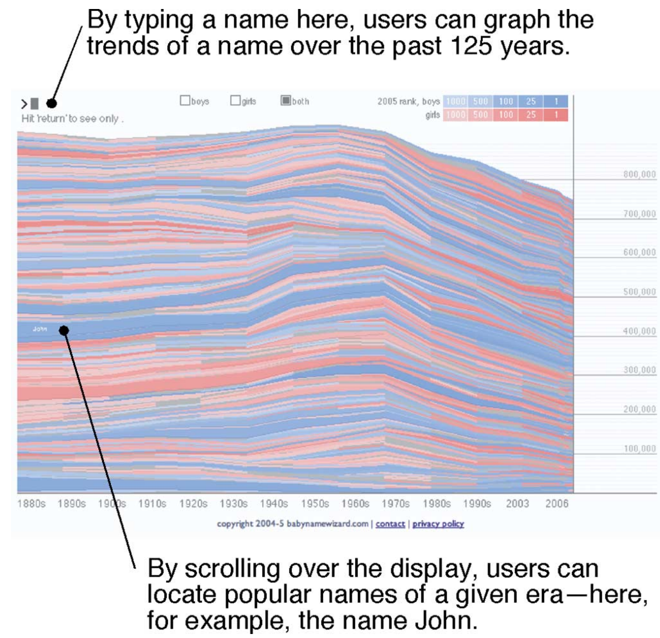


Fig. 7. Interactive NameVoyager software displaying the most popular baby names in the US from 1880s to the present [33]. Reprinted with permission of Laura Wattenberg.

Fig. 8. NameVoyager software displaying the popularity of "Elizabeth" from 1880s to the present [33]. Reprinted with permission of Laura Wattenberg.

over the graph reveals the ranking (from 1 to 1,000) of the name Elizabeth in any given era. Users can graph any names they wish, so long as the names appeared in the top 1,000 in a given year. In this way, individual users can continually tailor *NameVoyager* to their own goals.

Interactive maps are also a rich source of data that users can manipulate to explore data at various depths. For example, Fig. 9 shows the "USA National Gas Temperature Map," which

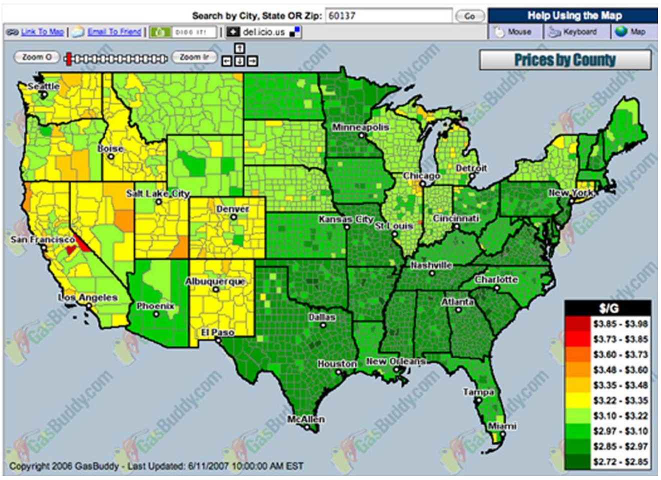


Fig. 9. Macro-level view of the USA National Gas Temperature Map [34]. Images provided by Gasbuddy.com.

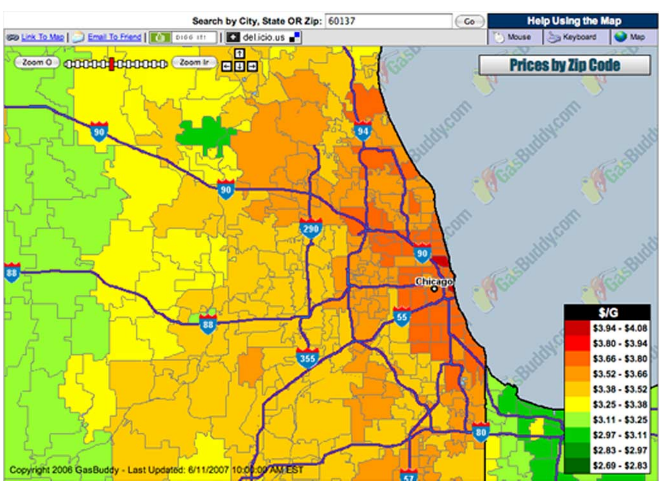


Fig. 10. Micro-level view of the USA National Gas Temperature Map showing the Chicago metropolitan area [34]. Images provided by Gasbuddy.com.

displays gasoline prices across the US [34]. On the macro-level, users can view the entire country to see how prices compare nationally by county and state, or they can zoom in to the micro-level to compare prices, as shown in Fig. 10, which displays the Chicago metropolitan area. Additional zooming enables users to map gas prices, almost literally, in their own neighborhoods. The rhetorical impact of this display would seem to be highly volatile because its kairos—or timing in a given situation—would be marginal when oil prices are stable and consumers drive little, but its kairos would intensify when oil prices spike upward during summer vacations, holidays, and international crises. For internet displays like this one, some "kairotic" moments may be unpredictable.

A more complex and sophisticated example of an interactive map can be found in the *New York Times* 2004 Election Guide of the US, which voters can use to assess information about the candidates, the issues, and the voting patterns and preferences of the electorate [35]. Users can select from numerous political contests (President, Senate, House, Governors) and then click on states to reveal additional data about a given contest. This interactive map supplies users with a rich pool of data that they can fish in as deeply and broadly as they like. Although its kairotic moment has passed for voters, the interactive map narrates compelling political stories that users can now read retrospectively and perhaps educate themselves as the next national election draws near.

Of course, interactivity does not assure clarity, and no amount of interactivity can compensate for a poorly conceived design. Usability research in human–computer interaction can help us understand how readers respond to various aspects of interactive design—color, zooming, and the like—by identifying optimal display techniques. Research in this field is underpinned by a cognitive-perceptual approach and appears in journals like *Human Factors* and in Card, Mackinlay, and Schneiderman's anthology *Readings in Information Visualization* [14]. Mirel critiques this kind of "object-oriented" research as too narrowly focused and she advocates, as a complement, usability studies that are situation-based and that account for the fuller rhetorical picture of a given user's experience [36]. Short of such holistic studies, user feedback can be looped into the design process. For example, internet visitors are counted, monitored, and often profiled, and they can contact designers with their input so that displays can be revised.

Animating Small Multiples Map animations can reveal both space and time, enabling users to visualize time geographically in what Tufte calls "small multiples," a series of miniature displays with the same plot frame and data variables [1, pp. 170–175]. However, instead of envisioning a handful of small multiples in a print display that is confined to a single visual field, animations can visualize dozens or even hundreds of small multiples that stream together to create a continuous display, revealing a much richer macro-level view of the data, as conceptualized in Fig. 11. Clarity is enhanced by the proximity

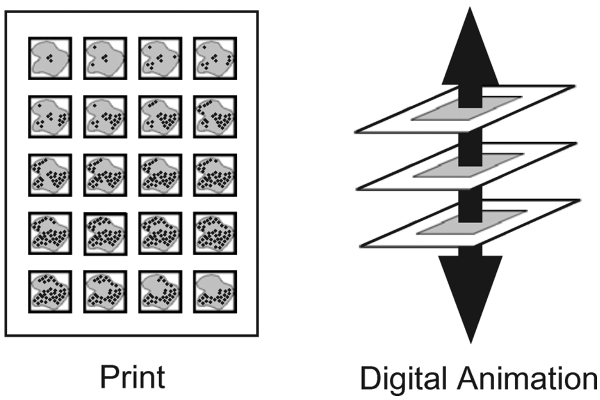


Fig. 11. Tufte's concept of "small multiples" [1, pp. 170–175], transferred from print to digital animation.

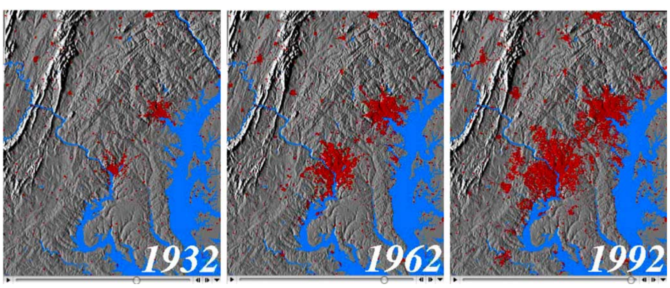


Fig. 12. Three of the small multiples in an online animated display of the Annual Population Growth in the Washington, D.C./Baltimore area from 1792 to 1992 [37]. Reprinted with permission of the U.S. Geological Survey and of Keith Clarke, Geography Department, University of California, Santa Barbara.

and speed with which users can process multiple displays in rapid succession.

For example, a website of the US Geological Survey and the University of California at Santa Barbara contains an animated map that shows the population growth of the Washington DC/Baltimore region over two centuries, with the density of the population data points progressively increasing as the story unfolds each year from 1792 to 1992 [37]. Along the way, users can stop the animation to get a micro-level view of the population data in any given year. Fig. 12 shows images for three of the years—1932, 1962, and 1992—that are displayed in the animation. In just seconds or minutes, digital animations like these can tell highly accessible, macro-level narratives.

Animated data displays demonstrate what Blair calls the "evocative power" of the visual, with many images appearing in rapid succession to create arguments [38, p. 51]. An animation with considerable "evocative power" appears on the Center for Remote Sensing of Ice Sheets (CReSIS)

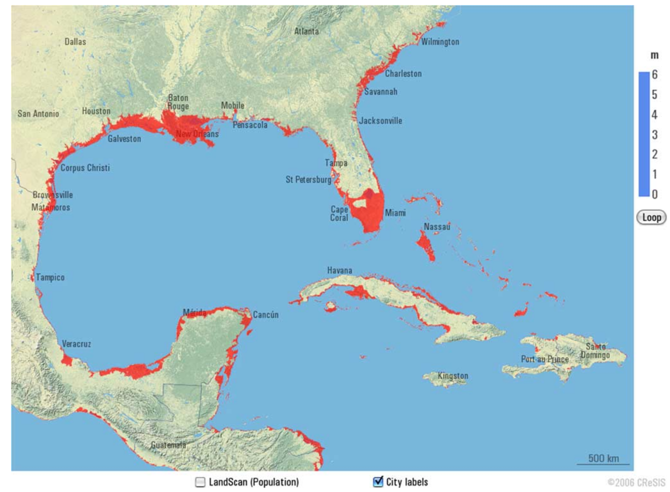


Fig. 13. Image from an online animation showing the effects of rising sea waters on the Southeastern United States [39]. Reprinted with permission of the Center for Remote Sensing of Ice Sheets (CReSIS), http://www.cresis.ku.edu/research/data/sea_level_rise/index.html.

website, which displays animated maps visualizing the effects of rising sea waters around the globe [39]. By visually narrating the incremental impact of rising waters on low-lying areas—such as Florida, the Netherlands, and Bangladesh—the maps create a stunningly powerful argument that global warming poses extreme danger to coastal communities. Users can select regional maps, which enlarge the images considerably, to focus on anywhere in the world they wish. Fig. 13 shows an image from the animated map for southeastern United States at six meters, which would undoubtedly alarm anyone living in south Florida or along the Atlantic or Gulf coast—or those with friends, relatives, or financial, political, or environmental interests in these areas. The micro- and macro-level clarity of sea waters streaming onto the mainland will certainly impel users to think seriously about the future.

The power of the animated narrative in multimodal form can be experienced in a dramatic map of Iraq that visualizes the daily distribution of casualties of coalition forces since the start of the war, plotting circular red bursts accompanied by audio gunfire to locate the place and magnitude [40]. Piecemeal war stories are thus threaded together into a coherent and compelling narrative that graphically and audibly represents the grim data. By vividly visualizing the heavy toll on human life, the animated map generates pathos appeals that arouse the reader's emotions about the war and thereby, as Dragga and Voss advocate, "humanizing" the data [41].

Impact on Conventions Although the interactive nature of digital display makes the user's experience with data visualization highly individual, this medium also has social consequences by proliferating existing genres like bar charts, lines graphs, and the like—conventions that lay readers come to understand and expect and that reinforce existing visual literacy standards. Because digital design is such a potent medium, it provides an avenue for inventing new forms of display, which because they appear online gives them the possibility, if not the prospect, of becoming conventions. Digital data design also sometimes develops its own graphing communities where conventions emerge and are shared among specialized groups of users [3].

Digital data design has the ability to reinvent displays that have appeared in the past but which were unsustainable because they were too complex or too labor-intensive to reproduce. Just like images and texts that have been revived and widely disseminated through digital technology, data displays can also reappear electronically. Mosaics, for example, are a type of area chart that shows several variables in the same display through rectilinear shapes that are proportionate to the data [13], [42]. Mosaics appeared as early as the *Statistical Atlas of the United States Based on the Results of the Ninth Census 1870* [24]. The image on the top in Fig. 14 shows a page of mosaics from this statistical atlas that visualize the population of each state, segmented into several groups. The image on the bottom in Fig. 14 shows an enlargement of the mosaic for Kentucky, with labels explaining each category of population.

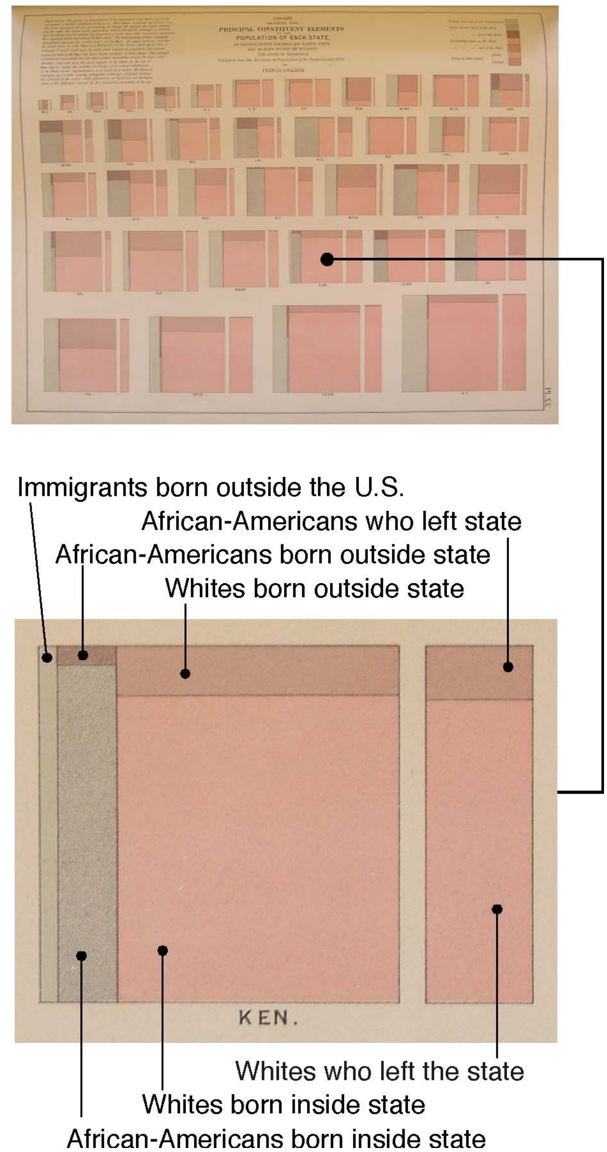


Fig. 14. Mosaics from the 1874 *Statistical Atlas of the United States* showing distributions of state population data (top) and a close-up of the mosaic for Kentucky (bottom) [24, p1. XX].

Clever in design and rich in information, mosaics failed to become a popular genre, probably because they were too time-consuming to create and possibly because they were too demanding interpretively for readers unaccustomed to reading displays of any kind and drawn initially to simpler forms of representing data. The production problem can be solved by an innovative piece of software—Manet: Missings Are Now Equally Treated—which enables designers to create a variety of plots, including mosaics [43]. Fig. 15 shows a mosaic created in Manet that displays hypothetical data about students in a university, categorized by college (Business, Engineering, or LAS), citizenship (US or international), sex, and rank (graduate or undergraduate), with graduate students in each category shown in red and undergraduates in gray. Because Manet is interactive, readers can select and reconfigure the variables to visualize a variety of plots [42], [43] (for additional examples of mosaics, see [13, pp. 20–23, 49], [44, pp. 382–385], [45, pp. 396–398]). To the uninitiated, learning to read mosaics can still be daunting in the 21st century, and thus clarity is far from assured. However, by actively engaging users in visualizing data, Manet diminishes the interpretive problem of learning a novel display system. User participation itself fosters clarity, as users learn by doing.

Many other graphical inventions that have languished in obscurity wait to be rediscovered digitally. The 19th century in Europe and America

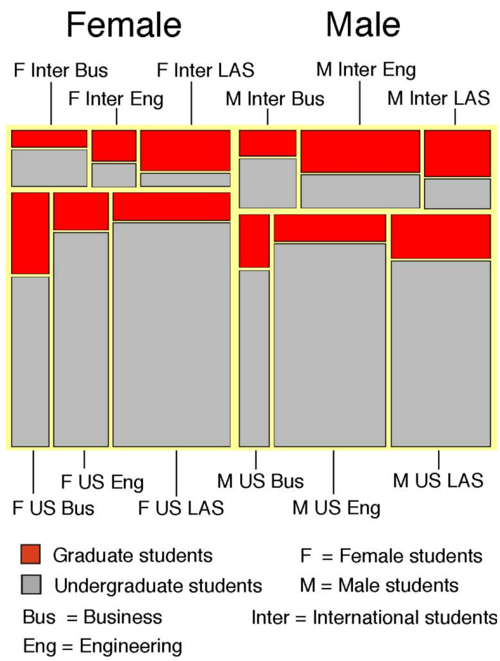


Fig. 15. Mosaic created with Manet software showing hypothetical data about university students [43].

(the golden era of statistical graphics) is a particularly fertile place to recover imaginative designs. Epic charts that correlate numerous variables on the same plot frame, wind roses that display weather and disease, [16, pp. 46, 113, 138–143], and bi-polar population distribution charts [25, pp. 219–221]—these are among the many forms that could be revived interactively in a digital age if designers had the curiosity and the technical skills to rediscover them [16]. Today their sustainability has a greater chance because technology makes them easier to reproduce and because readers participate in shaping their interactive successors.

Collaboration/Self-Expression Sometimes online interactive data displays not only ask readers to play an active role in shaping the display but also invite them to collaborate in the design process. The website "Information Aesthetics" provides a space where designers from around the world display innovative and experimental data designs in a wide variety of media—from paper and electronic to sculpture and clothes—and where readers post critiques, fostering a continuous conversation about data visualization [46]. In many of the examples on the Information Aesthetics website, data design functions as much as a vehicle for self-expression as for understanding, analysis, or decision-making. The rhetoric of this design is clearly expressive and even poetic, and functional usability is subordinate to the designer's desire to create a novel and aesthetically engaging artifact that elicits a subjective response from the user. The rhetoric of this design is highly expressive and even poetic, and clarity here is subsumed into an aesthetic experience.

CONCLUSION

Far from being simple and straightforward, clarity in data design is a multifaceted and sometimes ambiguous and elusive concept. Perceptual principles, cognitive models, aesthetics, the socializing influence of learning and experience, the exigencies of the rhetorical situation, as well as other rhetorical factors such as pathos elements that generate reader interest—all contribute something important to our understanding of clarity. As readers' encounters with data displays shift from print to screen, clarity is again redefined, partly because readers are often allowed control over how data are visualized. Interactive displays also afford readers access to complex data sets without having to process all of the data in the same display simultaneously, thus reducing their interpretive stress.

Over the **next** 50 years, technology will likely continue to fuel the revolution in data design, perhaps even surpassing the discoveries and innovations of the 19th century. The innovations in digital data design will afford readers even greater flexibility to visualize data, further democratizing visual access to information and intensifying the rhetoric of participation. As a result, readers will likely have a much larger array of internet-based conventional forms to interpret, as well as encounter many novel forms, all of which will compete for their attention. As these developments further redefine and expand visual literacy, the rhetoric of clarity will likely become even more fluid and contingent.

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