

## Ways of Seeing Data: Toward a Critical Literacy for Data Visualizations as Research Objects and Research Devices

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‘Every image embodies a way of seeing’ wrote the British art critic John Berger in his 1972 classic *Ways of Seeing* (Berger 1972, p. 10). Through the book and accompanying television series, he proposed elements of a critical literacy for making sense of the visual landscapes that we inhabit—from reproductions of art historical masterpieces to the advertising that adorns our cities and media environments. As well as guiding the attention of his viewers and readers around specific images, he also sought to examine the way in which images are reproduced and mediated (drawing on the

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work of the German philosopher and critic Walter Benjamin), as well as the broader social, cultural, economic, and political contexts around them.

In the digital age, data visualizations are becoming an increasingly prominent genre for the visual representation and mediation of collective life—from digital analytics dashboards to interactive news graphics. Similarly, data visualizations are becoming more and more popular in media and communications studies, and in the humanities and social sciences more broadly. According to Stephen Few, ‘data visualization is the graphical display of abstract information for two purposes: sense-making (also called data analysis) and communication’ (2014, n.p.). This might include, for example, the representation of information about numbers, words, relations, times, or locations. But why have data visualizations become so prevalent? And what does it mean to approach data visualization as a research device? What might it offer media and communications scholars? Data visualizations promise to assist us in making sense of complex data and complex phenomena, allowing us to simplify and bring order to dense information, for explanatory and communicative purposes. They may help us to analyze, filter, browse, and explore complex information. Paraphrasing Marshall McLuhan (1962), data visualizations are said to amplify our senses and our abilities to make sense of the world around us. Yet data visualizations are not a neutral tool. They come with particular ‘ways of seeing’, particular analytic, mediation, and narrative regimes regarding which we ought to be attentive as we use data visualizations to do research and tell stories.

Taking inspiration from Berger’s agenda, in this chapter we argue that the use of data visualizations as both instruments and objects of study requires commensurate forms of critical literacy. We also draw on Philip Agre’s (1997) notion of ‘critical technical practice’ for the social study of artificial intelligence and from Bernhard Rieder and Theo Röhle’s (2012) notion of ‘methodological reflexivity’ in relation to digital methods in the humanities and social sciences, both of which gesture toward forms of engagement with new research methods and technologies that are accompanied by critical reflection on their uses. We seek to extend Rieder and Röhle’s proposition that research practices ought to ‘oscillate [...] between concrete technical work and methodological reflexivity’ (2012, p. 80) to the practice of working with data visualizations.

We argue that data visualizations are not only bright adornments to our 21st-century information environments. They embody and engender not only particular ways of *seeing* (as Berger comments), but also ways

of *knowing* and ways of *organizing* collective life in our digital age. In other words, data visualizations reflect and articulate their own particular modes of rationality, epistemology, politics, culture, and experience. It is precisely to emphasize these ‘world-making’ capacities that in this chapter we prefer the term ‘device’ to the more commonly utilized term ‘tool’ to refer to data visualization. While the term ‘tool’ establishes the object as possessing coherence and connotes an instrumental relationship between user and object, this chapter proposes to develop an account of data visualization as device in order to draw attention to its capacity to ‘assemble and arrange the world in specific social and material patterns’ (Law and Ruppert 2013, p. 230). While arriving at media and communication studies with particular inscriptions as already described, following Law and Ruppert (2013) we argue that data visualization as a device is at the same time indeterminate and open to multiple and diverse forms of usage. For this reason, to follow Marres and Gerlitz (2015), deploying data visualization in media and communication research may be thought of as a process of developing mechanisms to align its affordances (and limitations) with the discipline-specific conventions of our fields. Given the growing role of data visualizations in our information environments, we think it is vital to develop a critical literacy to read, understand, and work with them.

We propose a three-part heuristic framework for what should be taken into account when reading, working with, and conducting research about data visualization. In doing so, this chapter does not aim to develop a practical guide for the effective use of visualization in media and communication research *per se*. Instead, we propose a framework to sensitize researchers to forms of mediation embedded in data visualization as a research device in order to support its critical and reflexive use.

This framework is organized around three forms of mediation that can be studied in relation to data visualization: (1) the mediation from *world to data* of the sources of information that underpin visualizations; (2) the mediation from *data to image* of the graphical representations of this information; and (3) the mediation from *image to eye* and the mind in the socially, culturally, and historically specific ‘ways of seeing’ engendered in the data visualization. Each of these three forms of mediation can be studied with a broad range of methods—from more familiar qualitative and quantitative approaches (such as visual and textual analysis, interviews, or surveys) to emerging digital and computational methods. We describe and illustrate these different forms of mediation, and ways of studying them, with reference to a collection of over two hundred data visualizations about public finances.

While for heuristic purposes our framework proposes the study of mediations between ‘world’, ‘data’, ‘image’, and ‘eye’, our intention is to provide a starting point to inform and broaden inquiry rather than to propose a neat and rigid distinction between these different elements. They are in fact mutually constitutive, such that data constitute as much as they represent the societal dynamics that they measure (Espeland and Stevens 2008) and regimes of measurement and visualization are generative of specific publics, practices, and cultures (Ruppert 2015). The forms of mediation we propose are also not exhaustive. For example, drawing on research on the reactivity of metrics (Espeland and Sauder 2007; Gerlitz and Lury 2014), a fourth layer of mediation could be formulated, concerned with the study of actions to intervene, respond to, and modify the dynamics that data visualizations capture. In addition to this, as the following sections will show, each of the three forms of mediation is actually constituted by multiple sublayers of mediation or inscription. These will vary according to the nature of the ‘research apparatus’ in which visualizations are embedded, in that different types of data and methods are accompanied by different types of inscription (Ruppert et al. 2013). We also do not hold a strict order with regard to the proposed layers of mediation.

The past few decades have seen the development of a body of literature dedicated to data visualization and information graphics. In particular, there is a growing body of books and articles offering practical guidance as well as showcasing different examples, techniques, and approaches.<sup>1</sup> This literature is itself interesting not only from a practical perspective, but also as a way to understand the forms of mediation involved in the composition of data visualizations—both those that receive attention and those that remain neglected—as well as the aesthetics, cultures, values, ideals, and practices associated with their production. These resources can be useful as a source for disassembling and understanding the making of data visualization projects.

While many of these works focus on a single layer of mediation—that of data to the image, looking at how information is translated into graphical form—we suggest that in using and studying data visualizations it is essential to grasp not just the production of images from data, but also the data sets and data infrastructures on which data visualizations draw, as well as the cultural practices and ideals implicated in the composition of visualizations that invite a particular way of seeing. There have been a number

of very informative works on this latter topic (for example Drucker 2014; Halpern 2015), which we will explore further later. Here our focus is less on data visualization as a field, but rather on developing the elements of a critical reflexivity that would accompany and inform the practice of data visualization in research and other contexts. This critical reflexivity is important not only in the study of data visualizations as objects, but also in improving our abilities to deploy them as research devices. We outline research outlooks and methods for studying all three forms of mediation, as well as pointing to further resources that may be useful for each one.

### AN EXAMPLE: VISUALIZING INFORMATION ABOUT PUBLIC FINANCES

To illustrate our proposed framework, we have chosen to work with a collection of data visualization projects about public finances. These include data visualization projects from media organizations, journalists, civil society organizations, and public institutions. This collection has been gathered in the context of research to map empirically how information about public finances is used in the service of democratic engagement with fiscal policy (Gray 2015a).<sup>2</sup>

There are two main reasons why we consider this thematic focus suitable to make our case. First, there is a long tradition of work exploring public finances with information graphics. Edward Tufte uses public finances to illustrate discussion of different techniques in his classic *The Visual Display of Quantitative Information*, citing a venerable tradition of information graphics that ‘nearly always create the impression that spending and debt are rapidly increasing’ (Tufte 2001, p. 65). He alludes to the fiscal information graphics of the Scottish engineer, economist, and pioneer of statistical graphics William Playfair, such as the one in Fig. 12.1.

The second reason is that there is a heterogeneous constellation of different issues and concerns that are associated with public finances and fiscal policy. As well as political and economic questions, from who in society pays how much tax and how public resources are allocated, many policy areas are underpinned by discussions about public finances, from international development to climate change. The complexity and competing narratives around this topic make it well suited to illustrate different approaches for studying data visualizations.

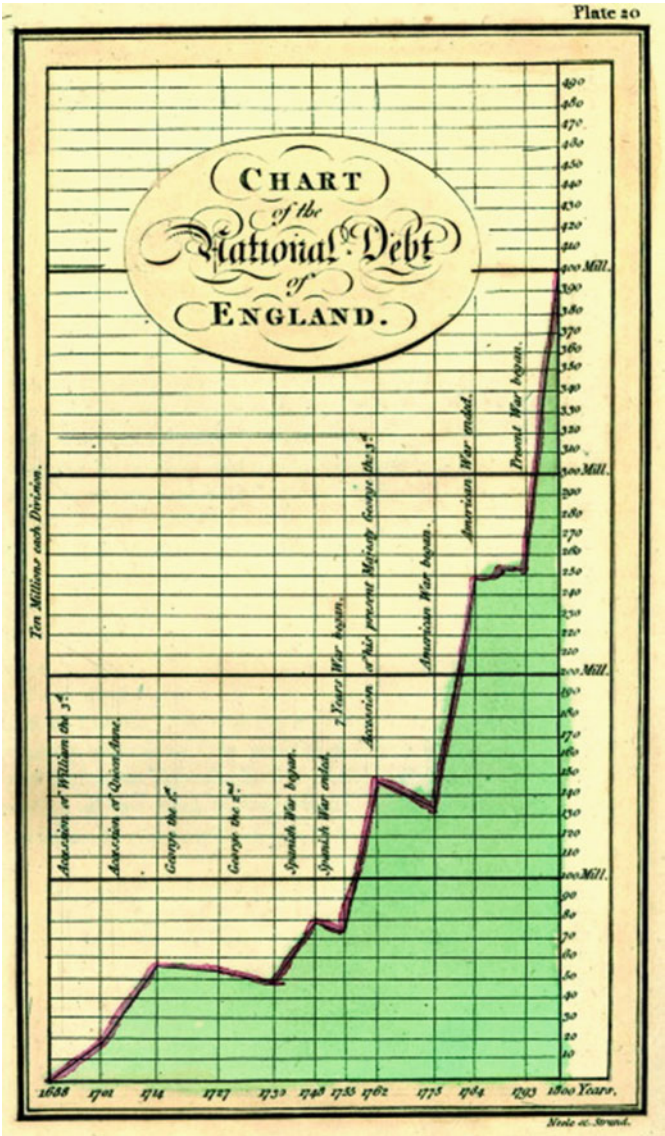


Fig. 12.1 ‘Chart of the national debt of England’ from William Playfair’s *The Commercial and Political Atlas* (Playfair 1801)

### THREE FORMS OF MEDIATION AND HOW TO STUDY THEM

In this section we will propose a research outlook and methods for studying each of the three forms of mediation implicated in the creation of data visualizations that we have outlined. This may serve as a checklist of questions and a menu of different methods that can be used.

#### *From World to Data*

As we shall see in the next section, many classic works on information visualization focus on the mediation of data to image—in particular focusing on the avoidance of misrepresentation. For example, Tufte suggests that ‘graphical excellence requires telling the truth about data’ (Tufte 2001, p. 51) and that data visualization designers should ‘let the data speak for itself’ (1997a, p. 45), championing an aesthetic program of ‘graphical integrity’ that we shall challenge and explore further. But what about the data themselves? How does the making of data shape the making of knowledge through visualizations?

Our first form of mediation to be studied is how the data used in the visualization are generated and how this process inscribes itself in the knowledge produced through data visualizations. This might include asking questions such as:

- What information and data are being represented in the visualization?
- What are the sources for this information? Where do the data come from?
- How are the data generated? What are the rationales, methods, and standards inscribed in the data infrastructures through which the data are generated?
- How are the data transformed or prepared?
- Which data sources are combined and how?
- How do the data selectively prioritize certain things over others?

The first step will often be establishing the data sources. In some cases details about the sources of the information will be explicitly referenced or linked to. In other cases additional work might be needed in order to identify these sources. This might be matching the precise tables or data sets that are used from a number of possible contenders (for example in cases where the institution or database is given, but not the exact table or data set); looking in the software source code or documentation of the



visualization to look for data sources; or conducting interviews with the creators of a data visualization to establish what data were used.

Once data sets are established for a given visualization, there are different approaches to studying and analyzing them. For example, the study of data sources might draw on literature about ‘sourcing practices’ from media studies and journalism studies (Cottle 2003; Manning 2001; Hall et al. 1978; Berkowitz 2009). Research can also be undertaken on the ‘data infrastructures’ implicated in the production of the data sets that are used in the visualizations. Drawing on previous work in this area, we take the phrase ‘data infrastructure’ to designate socio-technical systems implicated in the creation, processing, and distribution of data (see, for example, Akrich 1992). This might include elements such as standards bodies, software systems, administrative procedures, committees, consultancy processes, and many other things (Gray and Davies 2015).<sup>3</sup> Here it may be useful to draw on approaches from science and technology studies (STS) to trace the politics embedded in these systems—for instance through what has been called ‘infrastructure ethnography’ (see, for example, Star and Ruhleder 1996; Star 1999; Bowker and Star 1999). The composition of data infrastructures will lead to the production of different types of data, from statistical data to transactional ‘digital traces’ extracted from digital platforms.

How might we operationalize these approaches in relation to our collection of data visualizations about public money? First, can we *identify* the data sets that are used in the visualizations? The different ways of citing or linking to data sources are themselves something that can be studied, as they may reflect different kinds of ideals, norms, or practices of knowledge production. A cursory look at different data-sourcing practices reveals a wide range of ways in which data are obtained and prepared, as well as varying approaches to publishing details about data sets, software, and methodology.

In our collection, some of the projects simply cite the name of the department from which the data were derived. One example from the *New York Times* simply says ‘Source: Office of Management and Budget’, with no further details.<sup>4</sup> Many others give much more detail—including directly linking to data sets, or even providing documentation on methodology about how the data were sourced and transformed, what assumptions were made, and so on. For example, a piece from the US investigative news outlet *ProPublica* on ‘The Millions New York Counties Coulda Got’ is accompanied by a short methodological walkthrough titled ‘How We Analyzed New York County Tobacco Bonds’, explaining how the writers



obtained the data, which cash flow models they used and why, and the rationales behind other assumptions they made in the application.<sup>5</sup>

Publishing data sources has become *de rigueur* among some data journalism outlets. A piece from the *South China Morning Post* explains how data were extracted from PDF files and provides links to the ‘raw data’ used in the visualizations.<sup>6</sup> One data visualization from the *Guardian Datablog* gives an accompanying spreadsheet that lists a separate source URL (uniform resource locator) for every figure used.<sup>7</sup> If visualization projects publish the source code of their software, this can be studied in order to see the data files that have been used. For example, the Budget Key project by Israeli non-profit Public Knowledge Workshop links to the source code on the social software-sharing platform GitHub, which makes visible the changes and transformations that have been made on the data.<sup>8</sup>

As well as looking at the sourcing and transformation of the data, we might also look at the selection of particular data sets and tables to highlight or narrate certain aspects of public finances, such as spending, revenue, or debt. Rather than simply ‘telling the truth’ about public finances, these selections emphasize and de-emphasize different aspects of fiscal policy. We shall further examine the affordances of different visual forms in the next section. Suffice to say here that the selection of different data sets and tables is an important step that should be taken into account in the study of data visualizations, prior to their translation into graphical form. We can compare the data mediated in the visualization to the other data that are made available. Which indicators, subtables, or items of data have been selected, which have been left out, and how does this guide our attention toward some things and not others?

An interactive news application from *The Times* (UK) called ‘The Wall of Debt’ shows a dominant wall of red bricks depicting ‘national debt’, and a comparatively small green wall called ‘cuts’.<sup>9</sup> The visual editorial decision to select these two items is an important one in reading this interactive graphic, engaging with a particular political economic narrative about tackling public debt through spending cuts. Another short video clip called ‘Debtris’ by David McCandless presents a wide variety of other fiscal data points, ultimately highlighting how the global cost of the credit crisis dwarfs other sums such as the Organization of the Petroleum Exporting Countries’ climate change fund, the budget of the United Nations (UN), African debt to the West, and the funds needed to ‘save the Amazon rainforest’.<sup>10</sup> As well as looking at the selection of data on a case-by-case basis for individual visualizations, comparative analysis may be undertaken across a larger collection.

We might also study the composition of the data themselves. We could study the headers, categories, and classifications within the data sets to understand which variables and indicators are selected and prioritized. Content analysis of documentation and associated materials may provide further details about the units, forms of analysis, methodology, software, standards, and other details about how the data were generated. This might also be supplemented by interviews with those involved in the creation of the data about their decisions. It may be that data sets are generated from other, more complex database systems that may be of interest to study. In the case of public financial data, we might look into politics, rationales, and ways of knowing inscribed into the financial management information systems through which data sets about public finance are generated. These may be studied as socio-technical systems through, for example, document analysis and interviews. Sometimes there may be documentation manuals that explain how these systems function. In the case of public-sector data infrastructures, if details are not already published, then there may be routes for formally requesting them through access to information laws. Researchers and civil society groups interested in studying what was the most detailed source of information about public spending in the UK (the Combined Online Information System, or COINS) submitted official ‘freedom of information’ requests about the database. While their requests for its contents were initially turned down, they submitted follow-up requests asking about the database and training materials for it, which were successful.<sup>11</sup>

It may also be fruitful to study the categories and classification systems articulated by the data. For example, any of the data visualizations about public money uses different categories to describe different areas of expenditure. Where do these categories come from? How did they become the way they are? On the one hand we can look at the administrative contexts in which the data sets are generated, such as the organization of public-sector bodies. We might also look at which kinds of data standards shape public-sector data systems. For example, the UN COFOG (Classifications of Functions of Government) standard is widely used as a reference in order to facilitate comparability between different national budgeting processes.<sup>12</sup> This is particularly relevant when it comes to looking at visualizations including multiple countries, such as in international development or climate finance. The genesis of these data standards can also be studied through analysis of (historical) document collections, the study of information systems (for example, using approaches from software or platform studies), interviews, and ethnographic studies.

### *From Data to Image*

The second form of mediation in our heuristic framework is how visualizations mediate the data sources on which they draw into graphical form. This might include addressing questions such as:

- How are the data mediated into graphical form?
- What kinds of graphical techniques, methods, and technologies have been used?
- What are their affordances? How do they guide our attention toward different aspects of the data?
- What design decisions have been taken? What are their consequences?

These concerns are prominent in both research and practical literature around data visualizations. Edward Tufte talks of ‘graphical methods that *organize and order the flow of graphical information* presented to the eye’ (Tufte 2001, p. 154). He places a significant premium on the ‘graphical integrity’ of information visualizations such that they ‘defeat graphical distortion and ambiguity’ (Tufte 2001, p. 77). While this is one important way of looking at how data are mediated into graphical form, there are many other important aspects to study. Rather than just looking at accuracy, fidelity, and how graphics may be truthful or untruthful about data, we can also step back and look at their affordances—such as how they articulate structures and relationships or how they organize space, time, quantity, and categories in relation to the data.

In order to study these things, we may learn a great deal from contemporary literature about the creation of data visualizations, as well as classic literature on information graphics. These can be used in order to understand the composition of data visualizations, or to ‘reverse engineer’ them, which helps us to develop a critical and reflexive approach to the use of data visualization as a research device. Jacques Bertin’s 1967 *Semiology of Graphics* proposes a series of ‘retinal variables’ (1983, p. 9) including size, value, texture, color, orientation, and shape as a starting point for analyzing and working with different types of information graphics. This work provides an extensive and richly illustrated overview of how different ‘components’ of information can be mapped onto different visual forms. In a similar vein, Tufte’s *The Visual Display of Quantitative Information* contends that ‘data graphics visually display measured quantities by means of the combined use of points, lines, a coordinate system, numbers, symbols, words, shading and color’ (2001, p. 9).

While Bertin's work is explicitly limited to print graphics that fit on a 'sheet of white paper' (1983, p. 42) and many of Tufte's seminal works also focus on print graphics, many of the elements they discuss have been adopted and developed in relation to digital and interactive data visualizations. Thus we may read these influential works alongside other, more recent works that cover digital tools and methods in order to understand how different visual forms are implicated in the visualizations under study—including table graphics, maps, time lines, sparklines, networks, graphs, flow diagrams, small multiples, motion charts, bubble charts, and treemaps. These different forms can also be combined to highlight different aspects of the data. We may also look at the affordances of the software or the platforms that were used to create data visualizations (see, for example, Wright 2008; Manovich 2002, 2011, 2014). As well as desktop software applications, there is a growing number of visualization tools that enable visualizations to be generated and embedded. There is also a growing number of software libraries and components that are widely used to translate data into different graphical forms.

How might we use these approaches to study our collection of data visualizations about public money? We could look at the different graphical forms used in data visualizations to organize attention around different aspects of public finances. For our collection, this could include examining how different graphical elements are used in order to:

- Show a 'bigger picture' of breakdowns of totals into different categories.
- Put different figures into context.
- Show the geographic distribution of funds.
- Show trends or developments over time.
- Show breakdown of funds by sector or recipient.
- Show networks of financial flows.
- Compare different parts of the budgeting cycle (for example, commitments and actual expenditure).
- Compare revenues, expenditures, and debts.
- Show allocations per capita.

The formal characteristics of different visualizations in a collection can be studied with reference to either a pre-defined vocabulary of elements or through an 'open coding' or 'emergent coding' process (see Strauss and Corbin 1998). As similar visual elements can play different roles in different contexts, it is crucial to note not only their presence or absence,

but their *relations* with other elements in the visualization as a whole. For example, compare the use of bubbles in the visualizations in Figs. 12.2, 12.3, 12.4, 12.5, and 12.6).

With these examples we can see how the bubbles are arranged, scaled, and colored in order to draw out different characteristics of public finances—from representing hierarchical relationships in national budgets, to the locations of development funds, to health spending per capita over time, to spending per department over time, to relationships between recipients of public contracts, to the differences between commitments and spending. In each case, the bubbles are used in different ways to represent different things—with the position, size, and color having varying significance for each graphic. These different ways of organizing visual phenomena thus articulate and emphasize different ways of organizing knowledge about public finances.

As well as studying the characteristics of visualizations, their creators could be interviewed regarding their techniques, methods, software tools, and design choices. Where software repositories are available,

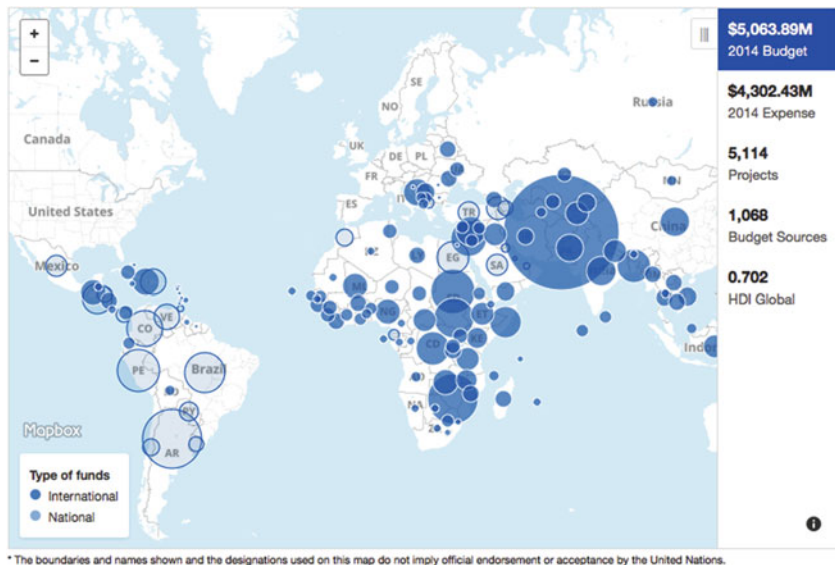


Fig. 12.2 Geographic distribution of international development spending (UNDP); <http://open.undp.org/#2014> (accessed 10 March 2016)

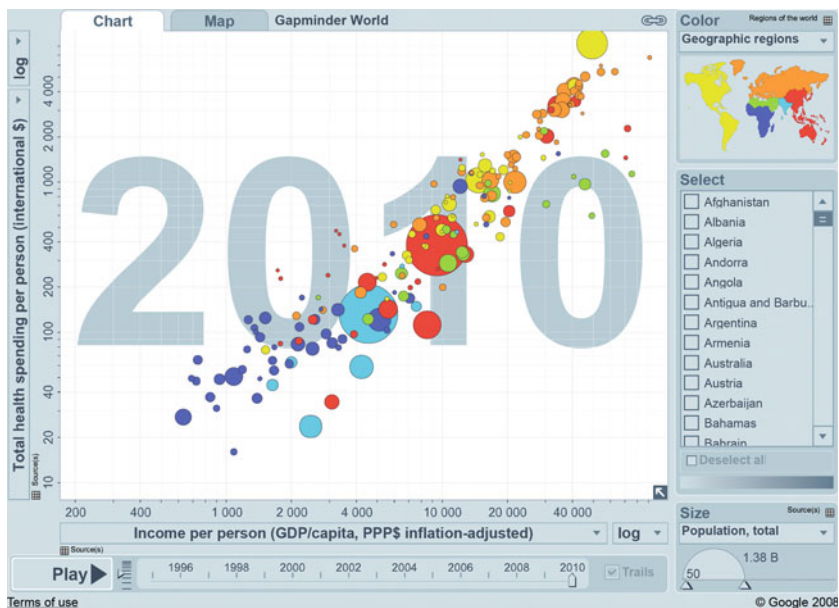


Fig. 12.3 Health spending per person compared with income per person over time; free material from <http://www.gapminder.org/world> (accessed 10 March 2016)

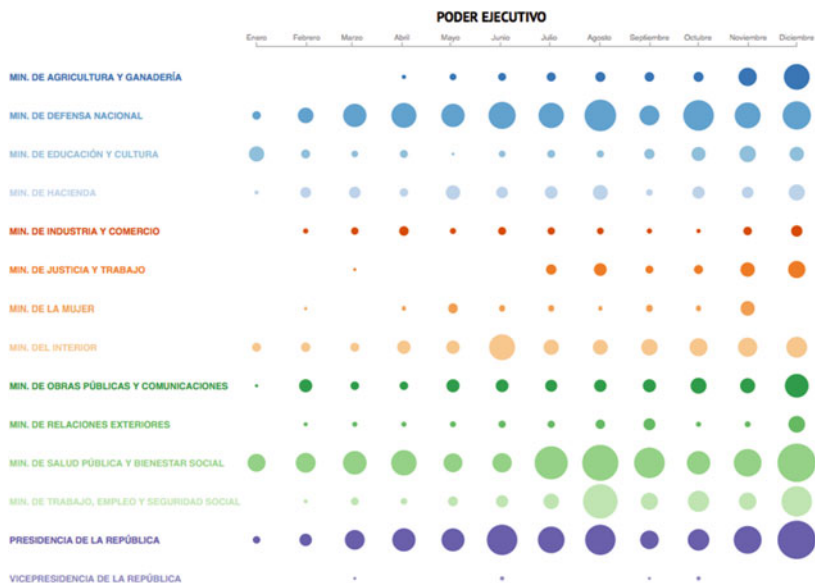


Fig. 12.4 Spending by different government departments over time (Government of Paraguay); <https://www.contrataciones.gov.py/datos/visualizaciones/contratos> (accessed 10 March 2016)

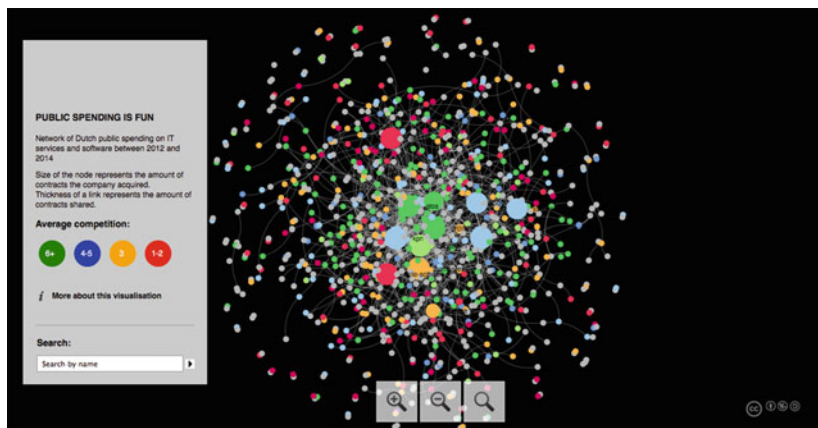


Fig. 12.5 Network of Dutch public spending on IT services and software (Adriana Homolova); <http://www.homolova.sk/dh/it/#> (accessed 10 March 2016)



Fig. 12.6 Comparing commitments and spending in Israeli budget (Budget Key); <http://www.obudget.org> (accessed 10 March 2016)



these can also be analyzed in order to understand how data sources are being mediated into graphics, whether for individual repositories or for collections. We might, for example, study repositories associated with fiscal data visualization projects on GitHub.<sup>13</sup>

### *From Image to Eye*

The third and final form of mediation in our heuristic framework is how the image appears to the eye and to the mind. As we saw in the last section, visualizations emphasize different aspects of data through design choices, techniques, and software that organize data into graphical form. However, these graphical forms also engender and depend on different socially, culturally, and historically contingent *ways of seeing data*. Hence we might ask:

- What kinds of visual cultures and practices are implicated or reflected in the data visualization? Where do these come from?
- What forms of usage are inscribed in the visualization? Who are the publics of the data visualization? How is it circulated, cited, and shared?

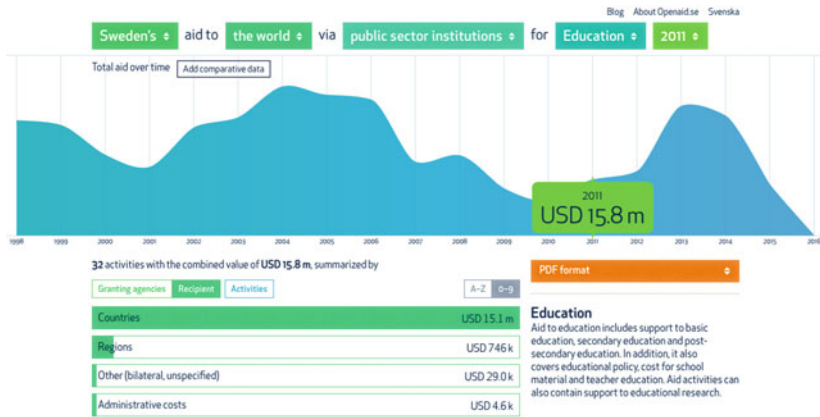
Rather than seeing the visual forms as neutral instruments for making evidence visible—or, as Tufte puts it, ‘instruments for reasoning about quantitative information’ (Tufte 2001, p. 9)—we can study their genealogies, aesthetics, and epistemological affordances to situate them in relation to other ideals, values, and practices. For example, visualizations can be read against the background of histories of science, technology, and modernity that explore the relationship between vision, knowledge, and image-making practices, from accounts of occidental ‘ocularcentricism’ (see Jay 1988) to the role of visual cultures in the development of conceptions of objectivity (see Daston and Galison 2010).

There have been several recent works that make the case for drawing on hermeneutic approaches from the humanities to enhance the study of data visualizations. For example, in her book *Graphesis*, Johanna Drucker advocates ‘critical study of viscosity from a humanistic perspective’ in order to ‘de-naturalize the increasingly familiar interface that has become so habitual in daily use’ (Drucker 2014, p. 9–10). She explores the emergence of contemporary ‘visual epistemology’ with reference to a broad range of developments in art, architecture, design, industry, philosophy, and computer science—from the emergence of graphical design

to interdisciplinary deliberations about visual abstraction between artists and designers associated with the Bauhaus school in Weimar Germany. In her *Beautiful Data*, Orit Halpern also similarly aims to ‘denaturalize and historically situate’ ideals and practices of data visualization (Halpern 2015). She traces the genesis of what she calls ‘communicative objectivity’ that has come to be associated with data visualizations, drawing on a different disciplinary constellation focusing on cybernetics, communication science, behavioral science, engineering, management studies, urban planning, and military research. There is also a growing body of literature focusing on the aesthetics of data visualization (see Manovich 2002; Jevbratt 2004; Lau and Vande Moere 2007; Whitelaw 2008; Sack 2011; Cubitt 2015) as well as on the development of different visual forms such as the time line (see Rosenberg and Grafton 2013) or those associated with network analysis (see Freeman 2004). The narrative dimension of data visualizations can also be studied (see Segel and Heer 2010; Venturini et al. 2016).

How might these kinds of approaches be adopted to study specific data visualizations, such as our collection about public finances? We could study the aesthetics of these visualizations—for example, the clean, minimalistic style adorned with primary-color palettes and icons that has become so widely adopted in many contemporary information graphics (Fig. 12.7).

This is similar to the aesthetic that Tufte advocates: championing efficiency and parsimony, maximizing the ‘data–ink’ ratio, and eliminating ‘chartjunk’. He proposes that ‘the design of statistical graphics is a universal matter [...] like mathematics’ and that insight into the design of visualizations may be obtained through the study of ‘excellence in art, architecture and prose’ (Tufte 2001, p. 10). Peter Galison (1990) has previously studied the links between architectural modernism and the universal aspirations of logic, mathematics, and philosophy in the first few decades of the 20th century. Many of the fiscal data visualizations in our collection look to share this aesthetic. Several of them incorporate icons or pictograms reminiscent of those associated with the Isotype Institute of Marie and Otto Neurath, which has exercised an important influence on the contemporary aesthetics of data visualization (Zambrano and Engelhardt 2008; Mayr and Schreder 2014; Headrick 2000; Rayward 2008; Fig. 12.8).



**Fig. 12.7** Openaid.se (Swedish International Development Cooperation Agency); <http://www.openaid.se/aid/2014> (accessed 10 March 2016)

Genealogical study may help to enrich research about what has given rise to the contingent forms that data visualizations may take, identifying a range of different influences and origins of different visual forms. Starting points may be provided through interviews with designers as well as content analysis of relevant design materials—which may be complemented with historical texts and archival research.

We might also study the specific visual forms that are transposed to mediate public money. Many visualizations are described and/or organized as dashboards, giving users an overview of multiple key indicators and trends over time in a single viewing pane, inviting narratives of oversight, optimization, balance, and control (see Tkacz 2015).

As well as studying data visualizations as cultural forms from a humanistic perspective, we can also trace their circulation, reception, and how they are used and viewed by different publics (see Kennedy et al. 2016). In addition to interviews and workshops, digital methods could be utilized to extract and analyze traces from digital platforms and online spaces in order to review the contexts in which visualizations are being used and shared (Rogers 2013). For example, we could query for names or URLs of projects on social media, search engine results, news media, or collections of documents. This may also help to chart the particular publics and context of usage of the visualizations—which can assist with their study as social and cultural forms.

## Home and Factory Weaving in England

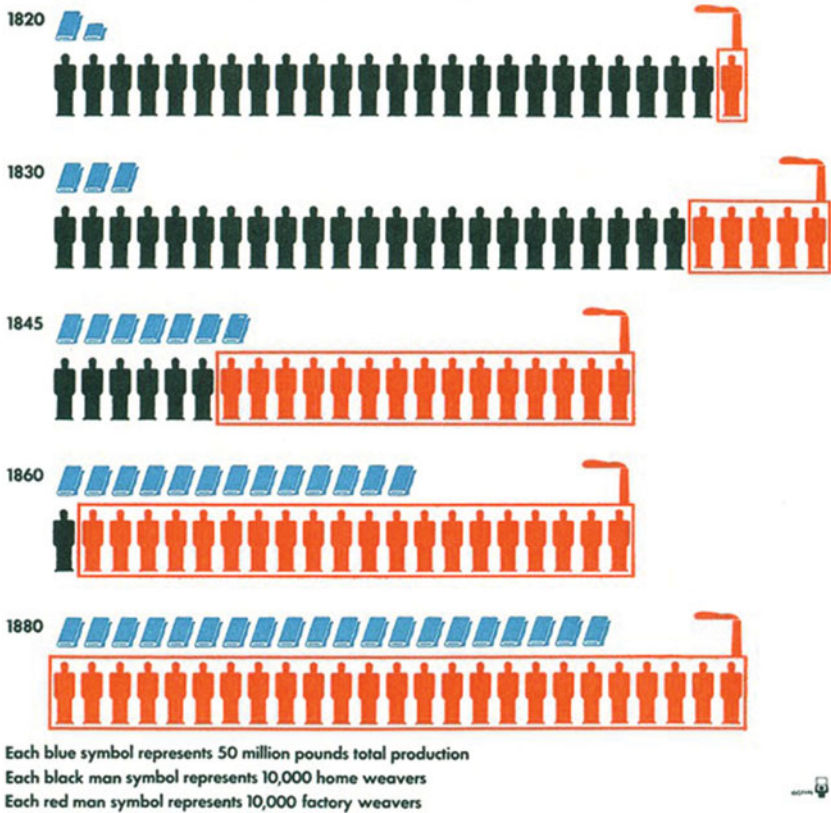


Fig. 12.8 'Home and Factory Weaving in England' (Neurath 1939)

## CONCLUSION

In this chapter we have proposed a heuristic framework that may be used to develop critical reflexivity around the use of data visualization as an object of research or a communicative or analytic device in research. We have illustrated this framework with reference to a collection of data visualizations about public money, and suggested some methods and approaches that could be used to study them.

First, we looked at the study of data sources, focusing on research approaches to examine how they selectively articulate and mediate different aspects of

the world—including how to identify sources, tracing how they have been transformed, and studying data infrastructures. Secondly, we looked at ways to study how the data sources are mediated into graphical form—including through the analysis of their visual properties, software, and design choices. Thirdly and finally, we looked at ways of studying graphical forms as socially, culturally, and historically contingent forms engendering different ways of seeing—including by tracing their diverse influences, and by analyzing their circulation and contexts of usage.

We hope that the study of these three forms of mediation through some of the approaches that we have discussed in this chapter may provide a useful starting point for researchers who wish to use data visualization as a research object or device. As data visualizations become more and more central, prominent, and familiar as ways of knowing and organizing phenomena, we think it becomes imperative to develop a richer understanding of the ways of seeing and ways of knowing that they engender. Just as Berger's *Ways of Seeing* helped to advance broader awareness of the critical study of images and visual culture, so we hope that further research in this area will advance literacy around ways of seeing data and ways of seeing with and through data visualizations. As visualization tools and practices become more and more ubiquitous, this might include not only the development of a critical *hermeneutics*, but also new kinds of self-reflexive *praxis* for the creation and reconfiguration of visualizations that are attentive to the forms of mediation that we have outlined. Experimentation in this direction might be informed by calls for non-reductive visualization (Manovich 2002), humanistic interfaces (Drucker 2014), feminist data visualization (D'Ignazio 2015), inventive methods (Lury and Wakeford 2012), rethinking dashboards (Tkacz 2015), and critical analytics (Rogers 2015).

## NOTES

1. See, for example: Cairo, 2012; Card et al., 1999; Cleveland, 1993, 1994; Few, 2009, 2012, 2013; Heller and Landers, 2014; Katz, 2012; Krum, 2013; Lima, 2011; McCandless, 2012, 2014; Meirelles, 2013; Munzner, 2014; Murray, 2013; Rendgen, 2014; Spence, 2014; Steele and Iliinsky, 2010; Tactical Technology Collective, 2014; Tufte, 1990, 1997a, 1997b, 2001; Yau, 2011, 2013.
2. For an extensive collection of examples of fiscal data visualizations see Gray (2015b).

3. Gray and Bounegru are currently working on another project on ‘data infrastructure literacy’, which includes further suggestions on approaches to studying and working with data infrastructures.
4. [http://www.nytimes.com/interactive/2010/02/02/us/politics/20100201-budget-porcupine-graphic.html?\\_r=0](http://www.nytimes.com/interactive/2010/02/02/us/politics/20100201-budget-porcupine-graphic.html?_r=0) (accessed 10 March 2016).
5. See <https://projects.propublica.org/graphics/ny-millions> and <https://www.propublica.org/article/how-we-analyzed-new-york-county-tobacco-bonds> (accessed 10 March 2016).
6. <http://widgets.scmp.com/infographic/20140304/budget2014/data> (accessed 10 March 2016).
7. <http://www.theguardian.com/news/datablog/2010/sep/22/tax-gap-information-beautiful> (accessed 10 March 2016).
8. <https://github.com/OpenBudget> (accessed 10 March 2016).
9. <http://appliedworks.co.uk/work/the-times-defining-a-new-era-of-data-journalism> (accessed 10 March 2016).
10. <https://www.youtube.com/watch?v=K7Pahd2X-eE> (accessed 10 March 2016).
11. [https://www.whatdotheyknow.com/request/schema\\_for\\_coins\\_database](https://www.whatdotheyknow.com/request/schema_for_coins_database) (accessed 10 March 2016).
12. <http://unstats.un.org/unsd/cr/registry/regcst.asp?Cl=4> (accessed 10 March 2016).
13. Bounegru and Gray are currently involved in developing tools and methods for working with metadata from GitHub as part of other research projects.

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