Data Visualization: An Untapped Potential for Political Participation and Civic Engagement

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Abstract. This article elaborates on the use of data visualization to promote a more informed and engaged participation in civic and democratic life. First, it outlines the main constraints and challenges in electronic participation research and concludes that the conventional deliberative approach to political participation has been impeding civic engagement. Then, through a couple of recent examples and a brief historical overview, it examines the power of data visualization. Following this, it explores the democratization of data visualization through four interconnected themes that provide new opportunities for political participation and civic engagement research: data storytelling, infographics, data physicalization, and the quantified self. The goal is to call attention to this space and encourage a larger community of researchers to explore the possibilities that data visualization can bring.

Keywords: Data visualization · Political participation · Civic engagement · Electronic democracy · Electronic participation

1 Introduction

For decades, scholars have put their faith in information and communication technology in facilitating a wide civic involvement in democracy [1]. However, despite technological advances and an increasing maturity of electronic participation scholarship, empirical studies suggest that much of the initiatives to date have largely failed to live up to the rhetoric. After an initial phase of excitement and exaggerated expectations, manifested in discourses about empowered individuals and a reinvigorated public sphere, it has become clear that democratic renewal through the telephone, cable TV, or the Internet, is not as straightforward as previously imagined [2]. Whereas the use of information and communication technology to enhance political participation and civic engagement has had a limited impact beyond academia, the last decade has witnessed a rapid popularization and democratization of data visualization. Widely appreciated for its ability to reduce information overload and make complex data accessible,

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data visualization has made its way out of the offices and on to the streets, our homes, and our computer screens and mobile devices. However, there have been few scholarly studies of data visualization that have aimed at promoting citizens' engagement with the institutions of representative democracy. In this paper, we explore how governments could better engage with the public through various forms of data visualization. In the following sections, we first summarize the main constraints and challenges of contemporary electronic participation research. We then, through a couple of recent well-known examples and a brief historical overview, describe the power of data visualization. Following this, we discuss the ongoing popularization and democratization of data visualization through four interconnected themes that represent a hitherto untapped potential for democratic engagement. Finally, some conclusions are drawn.

2 The Challenges to Online Citizen Engagement

Since the advent of the Web in the early 1990s, the prospects for electronic democracy have been viewed as heralding a new era of political participation and civic engagement. However, empirical studies suggest that most initiatives to date have failed to live up to expectations, despite large investments in research. For instance, Chadwick [3] says "the reality of online deliberation, whether judged in terms of quantity, its quality, or its impact on political behaviour and policy outcomes, is far removed from the ideals set out in the early to mid-1990s." Similarly, Norris and Reddick [4] say "few American local governments have adopted e-participation and those that have been adopted, for the most, have not implemented what we would consider meaningful citizen participation". Prieto-Martín, de Marcos, and Martínez [5] even go as far as to argue that "no real breakthrough or even any significant research milestone can be reported for the field." In sum, the proposed methods and technologies of electronic participation such as online deliberation are not perceived to have solved the problem of getting people to participate in the political process. Instead, just as in traditional offline methods of citizen consultation, we typically find a widespread lack of interest, which allows small groups to dominate participatory initiatives [6].

In order to provide a future direction for electronic participation, scholars have attempted to systematize current research and identify its main constraints and challenges. For example, Macintosh, Coleman, and Schneeberger [7] identified six main research challenges, barriers, and needs: the fragmentation of the research, immature research methods and designs, sociotechnical design, institutional resistance, equity, and theory. Other scholars have suggested that the problem with electronic democratic participation goes even deeper. Drawing on the social construction of technology approach, Johnson [8] argued that the concept of electronic democracy is fatally flawed and incompatible with liberal democracy. Electronic democracy is something more than the application of technology to politics: it embodies a particular set of practices and values. He points to three aspects of electronic democracy culture, in particular, that undermine key practices of liberal democracy: commodification (which undermines social equality), popular democracy (which undermines representation

and constitutionalism), and individualist publicity (the Internet's infrastructure enables mass surveillance, which undermines the voter's anonymity). Similarly, Coleman and Moss [9] argue that the assumed deliberative citizen is a construction driven by researchers effort to produce responsible, democratically reflexive citizens modeled on Habermas's discursive ideal of deliberative democracy. The authors acknowledge that the deliberative approach to civic dialogue is "unduly restrictive, discounting other important ways of making, receiving, and contesting public claims." They therefore encourage researchers in the field to be more open to a wider range of practices and technologies. This line of argument is supported by other scholars. Wright [10], for example, believes that the study of political deliberation online should be expanded and include different, informal "third spaces" beyond government-run websites and political-party controlled chat-rooms. Coleman and Moss [9] suggest that some of the most innovative participation research is being done in the area of computer-supported argument mapping and visualization. However, the visualization research they are referring to has primarily focused on facilitating large-scale online deliberation on the Web within a conventional rationalistic framework [11]. In general, visualization has been an underused technology in electronic participation research [12].

3 The Power of Data Visualization

Whereas the conventional approach to broadening democratic engagement and participation using the Internet has had a limited impact beyond academic circles, the past decade has seen a significant growth in the use of data visualization to reach a wide target audience. A prime example is Gore's narrated charts in the documentary *An Inconvenient Truth* [13]. In this film, which earned him and the Intergovernmental Panel on Climate Change the Nobel Peace Prize in 2007, Gore outlines the numbers behind man-made climate change by using a wide range of visualizations, including line charts, bar charts, and pictograms. Another prominent example is the approach developed by Rosling, a professor at the Karolinska Institutet, Stockholm, Sweden, and co-founder of the Gapminder Foundation [14]. Using the humor and drama of a sportscaster and a piece of software that turns seemingly dry data into colorful animated graphics, Rosling debunks myths about the developing world while making it an enjoyable experience. These observations, albeit involving only a few examples, suggest that data visualization has the potential for reaching out to a broad audience in innovative ways and facilitate greater citizen engagement in public affairs.

3.1 A Brief Historical Overview

To the casual observer, it would appear that data visualization is a recent phenomenon. In fact, the graphical portrayal of quantitative information has a long and rich history. According to Friendly [15], the beginnings of modern statistical graphics can be found in the scientific discoveries, technological advances, and societal developments in the 17th and 18th centuries, in particular, in analytic

geometry and coordinate systems, probability and statistical theory, state statistics, and new technologies for measurement, recording, and printing. Many visualization techniques that are still being used today were introduced during this period, including the line chart, bar chart, and pie chart. The Scottish Enlightenment scientist William Playfair invented or greatly improved these techniques, and is generally referred to as the father of the graphical method in statistics [16].

In the second half of the 19th century, a number of developments combined to produce a "Golden Age of Statistical Graphics" [17]. Three well-known and much-discussed examples from this period that illustrate the power of visual rhetoric include Snow's dot map of a cholera outbreak in London [18], Nightingale's polar area ("coxcombs") charts displaying the mortality rates of British soldiers during the Crimean War [19], and Minard's multivariate display of Napoleon's march on Russia [20]. Snow and Nightingale used their charts successfully as critical evidentiary statements in campaigning for improved sanitation, which eventually led to government healthcare reforms.

In the first half of the 20th century, the earlier enthusiasm for statistical graphs and maps was supplanted by the rise of mathematical statistics [15]. Few graphical innovations were introduced during this period; it was, however, a time for consolidation and popularization. An important factor in the diffusion of this was pictorial statistics, or, pictograms [21]. An influential advocate of pictograms was the Austrian philosopher Otto Neurath, who developed a visual language known as Isotype (International System of Typographic Picture Education), with the purpose of explaining societal developments to the broad, uneducated public [22]. Neurath's own assumption, "to remember simplified pictures is better than to forget accurate figures," captures the general idea [23]. Due to the association of Isotype with left-wing movements and Soviet propaganda, the method disappeared in the Western world during the Cold War, and its legacy has there gone either unnoticed or unappreciated [24]. Nevertheless, the influence of Isotype reverberates through much of our present visual communication, and in the last decade, the method has received renewed interest and increased attention. For example, Mayr and Schreder [25] review Isotype with respect to its potential for today's civic education and participation, and propose we should rediscover its core principles and adapt them to the modern context.

The period from 1950 to 1975 constituted a rebirth for data visualization. Friendly [15] lists three significant events that contributed to this upswing. The first was the publication of Tukey's book *Exploratory Data Analysis* [26], which introduced a new approach to statistics that used the power of visualization as a means to explore and make sense of data. Second, Bertin's book *Sémiologie graphique* [27] was the first attempt to propose a theory of graphical display of data used in maps, diagrams, and networks. The third was the introduction of computers, programming languages, and software for statistical graphs.

In 1983, Tufte published the classic *The Visual Display of Quantitative Information* [28]. In this book, Tufte famously criticized the use of "chartjunk," i.e., unnecessary or distracting visual embellishment included in data graphics. Instead, he advocated the practice of graphical excellence, guided by the fundamental principle: "Above all else show the data" [28]. This principle is formalized

in the data–ink ratio rule, which states that the proportion of ink devoted to the non-redundant display of data in the total amount of ink used in the graph should be maximized. Tufte's minimal design aesthetic has had a strong impact on the data visualization community and he is frequently referred to throughout the literature. However, recent empirical studies suggest that visual embellishments can, when properly designed, support the comprehensibility and memorability of a data display [29].

A decade later, Cleveland published two companion volumes, *Visualizing Data* [30] and *The Elements of Graphing Data* [31]. In these books, Cleveland reanalyzes many data sets from the scientific literature and demonstrates the use of graphical methods for studying the structure of data. Similar to Tufte, Cleveland considers clarity a vital aspect of graphing data and suggests the following overall guiding principle: "Make the data stand out. Avoid superfluity [31]." In 1999, Wilkinson published *The Grammar of Graphics* [32] based on his extensive programming experience acquired during writing the SYSTAT and the SPSS statistical packages. The book presented a new multilayered approach to data graphics, later extended and implemented as an open-source R package, ggplot2 [33]. In the same year, Card, Mackinlay, and Shneiderman [34] published a collection of seminal papers under the title *Readings in Information Visualization* which established information visualization as a distinct field separate from scientific visualization.

As previously mentioned, data visualization has exploded in the last ten years. In terms of authorship, one figure perhaps worthy of special note is Stephen Few, author of several approachable textbooks on data visualization that teach fundamental concepts and visualization techniques with a particular focus on the needs of business [35]. If Tufte's 1983 book is the classic on static printed statistical graphics, Few's books are rightly the best practical introductions to computer-based data visualization. Along with an increasing body of literature, the past decade has seen the emergence of a vast array of programming languages, toolkits, and libraries for interactive web-based data visualization. Prefuse, for example, was an early visualization framework using the Java programming language [36]. However, Java is becoming increasingly outdated for interactive and animated web graphics. Instead, JavaScript, the standard language for interactive web content, has become the preferred choice also for data visualization. Today, many web-based data visualizations are often built with D3, WebGL, and other JavaScript frameworks, that use web standards and do not require web browser plug-ins [37].

4 Democratizing Data Visualization

In this section, we explore four interconnected and overlapping themes that contribute to a popularization and democratization of data visualization: infographics (viral visualization), data storytelling (narrative visualization), data physicalization (physical visualization), and the quantified self (personal visualization). Similar to Danziger's [38] four design dimensions for public-facing

information visualization, the themes presented here should not be viewed as comprehensive, but rather as stimuli to the research community to begin to ask better questions regarding the design of future technologies and practices for political participation and civic engagement.

4.1 Data Storytelling

Up to now, data visualization beyond the simple pie or bar chart has been the domain of specialists trained in either statistics or computer science. This was particularly true if dynamic and interactive charts and diagrams were required. However, the last few years have seen the emergence of a new class of self-service applications that support the creation of ad hoc visual analysis and dynamic data querying on standard personal computers. This new breed of user-friendly data exploration and visualization tools empowers the average users, as it makes them less dependent on technical expertise. One example is Fusion Tables, a web application by Google for gathering, visualizing, and sharing data. Another example is Tableau Public, from Tableau Software, which features a simple drag and drop interface for creating interactive visualizations. Yet another tool with similar functionalities is Qlik Sense, provided by the company Qlik. This class of applications, which are typically available free, enables a broad audience to tell stories with data using visualization. A typical case is a journalist who wants to use interactive visualization to turn inaccessible data into an engaging story and publish it online. This approach, frequently referred to as data journalism [39], data storytelling [40], or narrative visualization [41], emerged in news organizations, such as *The Guardian* and the *New York Times*, as a response to the disruptive forces of digitization and media convergence. An example of an interactive data-driven story using visualization is the *New York Times*'s dialect quiz "How Y'all, Youse, and You Guys Talk" [42]. By responding to 25 different questions about the language the user is most likely to use in different situations, the quiz builds a profile of the user's dialect. When all the questions have been completed, a heat map indicates where in the United States the user would be most likely to find a person who uses a similar dialect. The user is also given the opportunity to share their map through popular social networks or email. The dialect quiz became a huge success: In just eleven days (it was published on December 21) it became the most visited content of 2013 throughout NYTimes.com, their mobile site, and iOS apps [43].

4.2 Infographics

Information graphics, a popular form of visualization commonly found in news media and often referred to as infographics, has exploded in the digital age. A Google search on the term "infographics" at the time of writing of this article returned 56 million results. To put that number into context, searches on the terms "data visualization" and "information visualization" returned 6.6 million and 0.5 million results, respectively. Businesses use infographics to connect with potential customers, drive website traffic, and increase brand awareness [44].

Non-governmental organizations use them to enhance their communication in outreach and advocacy efforts [45]. Governments release infographics on their websites to convey the current state of public matters [46]. The typical online infographic is a static high-resolution graphic design that attempts to transform abstract or complex information about a specific topic or issue into a format that is visually engaging, easily understood, and easily shared. Infographics combine data with design—numbers, data displays, words, and pictures—in order to inform, entertain, or persuade their audience.

Despite the proliferation of infographics in today's fast-paced digital society, little research has been conducted on them. However, they typically share a number of attributes. Similar to the idea behind micro-blogging services such as Twitter, the main characteristic of infographics is that their purpose is to tell the gist of a story at a glance. They are stand-alone or self-contained visuals that are easy to digest and do not require additional information to be comprehensible. A second important characteristic is that infographics are meant to be aesthetically pleasing: what social media consultant Mark Smiciklas has called the "cool factor" [47], paying particular attention to the use of color, typography, icons, and composition. Indeed, well-executed infographics are often admired for their beauty or for bringing out the beauty in data. A third characteristic of online infographics is that they are viral: easily shared and spread across social networks from person to person through "word of mouse."

Although infographics are generally considered effective for disseminating information to the masses, statisticians and others have criticized them for relying too much on style over substance [48,49]. Clearly, many infographics are nothing more than eye candy that publishers and marketers use to gloss up their content: overly designed and conveying little meaning. A surprisingly large number of infographics deceive their viewers by cherry picking statistics, warping the facts, or providing questionable, vague, or nonexistent data sources [50]. Despite these ethical objections, the sharp increase of online infographics in the last five years suggests that they appeal to a broad audience, a fact that makes them worth investigating further.

4.3 Data Physicalization

Physical data visualization, a lesser known sub-field of data visualization, studies alternative data representations where the data is not represented through pixels on a computer screen, but via physical modalities experienced directly through the eye (not including ink on paper) or other human senses. In contrast to conventional data visualization, where objectivity is the norm, physical representations of data allow of, and sometimes even encourage, the inclusion of subjectivity in order to be evocative and increase the onlooker's engagement. Typically, the alternative data mappings employed in physical visualizations may not be immediately recognizable, but instead be discovered through interaction, association, and reflection. In an overview paper, Vande Moere [51] explores the design space of physical data visualization in casual or non-professional contexts. He lists five genres: data sculptures, ambient displays, pixel sculptures,

object augmentation, wearable visualization, and alternative modalities. Data sculptures are data-driven physical artifacts that can be touched and explored through a tangible user interface. In the first study of its kind, Jansen, Dragicevic, and Fekete [52] compared data sculptures to screen-based visualizations, using three-dimensional bar charts as an example, and found that the physical bar charts improved the users' efficiency at information retrieval tasks, see Fig. 1.

Fig. 1. A physical three-dimensional bar chart made of laser-cut acrylic automatically generated from data. Each bar was spray-painted and mounted on a base together with two scales made from transparent acrylic sheets on which axis labels and lines were engraved. Country and year labels were engraved on all four sides of the base using a vertical orientation.

Ambient displays turn architectural spaces into a data display through subtle changes in light, sound, movement, solids, liquids, or gases that can be processed in the background of awareness. Envisioned as being all around us, ambient displays blur the boundary between the physical and digital worlds to create an interface between people and digital information. Pixel sculptures use non screen-based visual units for representing information. For example, there are the synchronized mass games or gymnastics, often seen at the Olympic Games, where each individual makes up an element in a giant mosaic picture. Object augmentation refers to superimposing everyday objects with information. Visual animated projections on building facades and sidewalks are common examples. Wearable visualization draws on miniature computing devices that fit in clothing, jewelry, and other things that can be worn over long periods. The last category, alternative modalities, uses non-visual representations of data that can be experienced through sound (sonification or auditory displays), touch (tactile or haptic displays), smell (olfactory displays), or taste (palatable interfaces). For instance, an experimental workshop called Data Cuisine explored food using culinary means as an alternative medium for representing data [53].

4.4 Quantified Self

Self-knowledge through numbers, the motto of the quantified self grassroots movement [54], is quickly becoming a mainstream phenomenon. Currently it

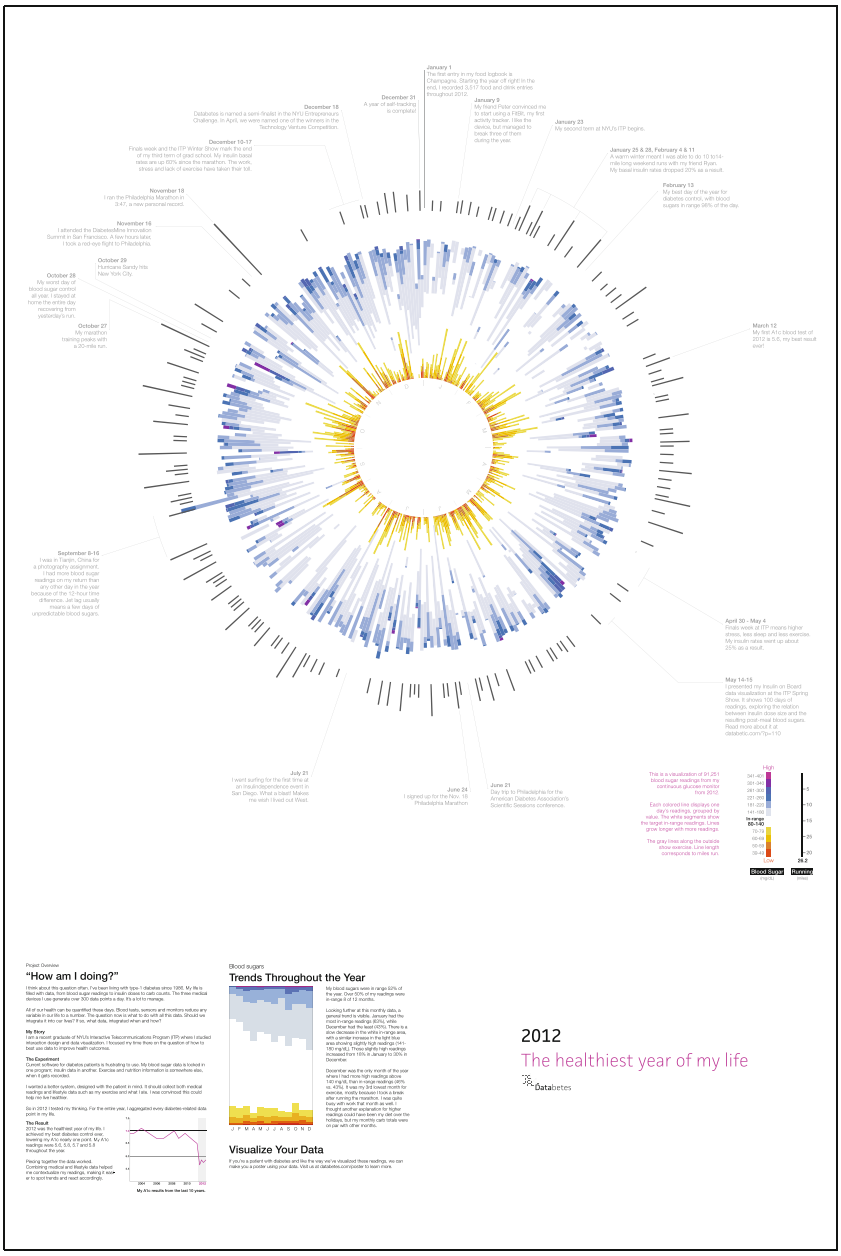

Fig. 2. The poster *2012 The healthiest year of my life* by Doug Kanter. The main circular graph displays 91,251 blood sugar readings from his glucose monitor with each line indicating one day. High blood sugar levels are shown in colder colors, and low blood sugar levels are in warmer colors. Along the outside of the circle are dark gray lines showing how much he ran each day. Notes for significant events are listed throughout the year in order to contextualize the medical readings.

is estimated that one in five adults in the United States are tracking their physical activity, sleep pattern, nutritional intake, and many other things related to their lives, through a portable or wearable computing device such as a smartphone, smartwatch, or activity tracker [55]. The basic idea is simple: Through more granular around-the-clock quantified monitoring, people can make smarter lifestyle choices and live healthier, more active lives.

Anyone interested in measuring their well-being and becoming more self-reflexive through the prism of performance data can choose from a variety of consumer-oriented products on the market or simply download and install a health and fitness application on their smartphone. Large technology companies, as well as more established producers of navigation and fitness equipment, are presently investing heavily in personal health and wellness technologies. Typically, these applications and devices are paired with a website for data management and visualization, social networking, personal recommendations, and action plans. Some services also include gamification features, such as challenges, leader-boards, and virtual awards, drawing on theories of behavioral economics to keep users motivated and engaged [56].

The reasons for self-surveillance are numerous and varied and range from those of the causal fitness-tracker who monitors their own exercise, to those of tech-savvy patients and citizen scientists who share their medical and lifestyle data online to help others and advance research, to those of life-logging enthusiasts with a passion for self-discovery through personal analytics. The story of Doug Kanter, who blogs about living with diabetes at databetic.com, offers a glimpse of what the future of personal data quantification might look like [57]. In 2012, he used a suite of medical devices, activity trackers, smartphone applications, and PC software to record all his diabetes data and physical activities. Kanter visualized his yearlong quantified self project as a poster displaying every blood sugar reading, every insulin dose, and every meal, as well as all activity data he tracked in 2012, see Fig. 2. Kanter's systematic self-tracking approach helped him become more aware of his behavior and provided an opportunity for change. As a result, his diabetic control improved considerably, making 2012 the healthiest year of his life.

5 Conclusions

In this article, we have explored the potential of using data visualization to promote political participation and civic engagement. First, we reviewed the main constraints and challenges of contemporary electronic participation research and found that it cautions us to reduce our expectations of the conventional approach to online participation since there is little evidence of its success. In particular, it suggests that the rationalistic model based on deliberative theory has become a straightjacket, impeding wide civic involvement. This predicament has prompted some scholars to rethink their earlier views, and to suggest that the study of online participation should be expanded to incorporate a wider range of technologies and practices. As a response to this call, we examined the power

of data visualization through a couple of recent examples and a brief historical overview. We then explored four overlapping themes that contribute to an ongoing popularization and democratization of data visualization: data storytelling (narrative visualization), infographics (viral visualization), data physicalization (physical visualization), and the quantified self (personal visualization). All four themes suggest that data visualization has a yet untapped potential for promoting a more informed and engaged participation in civic and democratic life. An important aspect of this technological transformation is the empowerment that visualization can bring about through a more direct and personal interaction with data. When people are given the opportunity to explore data on their own, they become empowered to take responsibility and enact change, both individually and collectively. Moreover, as people adapt to new flows and contours of data, statistical literacy is likely to become increasingly important and eventually a necessity for efficient citizenship in information-laden societies. Data visualization, in all its various forms and expressions, may prove to be an important factor in developing this competence.

The themes and examples discussed in this paper are suggestive (but by no means conclusive) evidence that the time is ripe for scholars to consider the use of data visualization in electronic participation research. However, the versatility and potential applications of data visualization in the service of democracy remain to be explored. I would like, therefore, to invite my colleagues to join me in exploring and reflecting on the following research questions:

- Techniques of storytelling focus on people, motives, and contexts, rather than on numbers. How can stories help bring data to life?
- Aesthetics reaches us at a different level than words and numbers alone. How can data be combined with art and design to evoke emotional engagement?
- In today's networked society, harnessing the power of human connections is key. How can we make data conversational and sharable?
- Beyond-the-desktop visualizations may be effective in engaging hard to reach groups. How can we unlock the hidden potential of tangible data?
- Smartphones and other connected devices bring visualization closer to people than ever before. How can we leverage the ubiquity of data in people's lives?

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