Data Visualization in Review: Summary

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There has been a recent surge of interest in data visualizations and their potential to communicate effectively. While in the past data visualization was viewed as an important analytical tool for researchers, it is quickly being recognized as an essential aspect of effective research communication.

Although data visualization is fairly new for development researchers, it affords opportunities to both transform and display data (Lindquist, 2011b). Visualization experts say that these capabilities are extremely useful within complex and changing environments, which are akin to the contexts surrounding IDRC-supported projects. As Evert Lindquist argues, “visualization techniques loom as potentially important sense-making, analytic and communications tools for capturing and addressing complexity. The promise is that, if properly chosen and calibrated, they can show the breadth and evolutions of problems and interventions, permit more detailed explorations of facets and strands, as well as how these facets and strands link to the whole (Lindquist, 2011a: 3).”

This study assesses the potential of data visualization to assist in effectively communicating research for influence.

Assessing the Field

Defining data visualization

The definition of data visualization is far from simple, since the term and its corresponding synonyms lack clear distinction and agreed-upon definitions. Terms like data visualization, information visualization, and infographics have also been used interchangeably despite arguments for clear distinctions. This study explicitly adopted the term data visualization because of the reference and emphasis on the word data; which lies at the heart of IDRC-supported research. The use of the term data visualization within this report is therefore not limited to the display of raw data sets, but rather all static and interactive visual representations of research data, which may include infographics.

Data visualization as a field

Although data visualization has only recently been recognized as a distinct discipline, it has deep roots dating back to second century cartographers and surveyors. Ancient Egyptians surveyors organized celestial bodies into tables to assist with the laying out of towns and the creation of navigational maps to aid exploration (Friendly, 2008). It was only during the 17th century, when French philosopher and mathematician René Descartes developed a two-dimensional coordinate system for displaying values along horizontal and vertical axes, that graphing began to take shape (Few 2012). During the late 18th century, Scottish social scientist William Playfair changed the field of visualization by pioneering many of today’s widely used visualizations – including the line graph and bar chart (Playfair, 1786), and then later the pie chart and circle graph (Playfair, 1801).

During the 19th century, modern forms of statistical graphs were invented including; pie charts, histograms, time-series plots, contour plots, scatterplots, and many more. Scholars were also experimenting with thematic cartography, in order to display an array of economic, social, medical, and physical data on maps (Friendly, 2006).
Today, the world is experiencing another surge in data visualization popularity. This interest can be partially linked to the increased availability of new technologies and software products which enable every user to dabble in the world of visualization. Although there are different streams within the field of data visualization, “all see visualization as having great promise as a superior way to render information for illumination and decision-making; and all try to balance and improve the aesthetic and practical qualities of visualization…” (Lindquist, 2011b, 15).

Exploring data through visualization was popularized in 1973 by statistician Francis Anscombe, who designed Anscombe’s quartet, a series of four datasets with identical means, modes, and averages (see Figure 1 above). Anscombe demonstrated that the difference among these datasets is easily seen when graphed.

Visual science has demonstrated that data visualizations are particularly effective in communicating or explaining data to an identified audience, if the visualizations are calibrated correctly to draw on the brain’s ability to detect certain properties. If visualizations are properly designed they not only increase the speed at which data is comprehended, but can also increase the retention of data. Visual perception utilizes the eyes, a channel which has one of the largest “band-widths” to the brain of all our senses (Kosara et al., 2002). The eyes transmit information from 100 million receptors through a million fibres in the optic nerve (Ware, 2004). Visual details are registered at greater detail from the very center of our visual field, as opposed to the periphery. In the center, the eye can resolve about 100 points at the edge of a pin (held at an arm’s length away); whereas at the edge of our visual field objects need to be the size of a head to be registered.
Ware highlights that “the non-uniformity of the visual processing power is such that half our visual brain power is directed to processing less than 5 percent of the visual world... non-uniformity is also one of the key pieces of evidence showing that we do not comprehend the world all at once (Ware, 2004, 6).

Instead of perceiving the entire visual field in a single glance, the eyes are thus forced to move and scan throughout this field, refocusing and registering different details. This information is distilled in the visual cortex, which is extremely fast and efficient, as compared to the cerebral cortex, which is slower and is largely used for other cognitive tasks (Few, 2010).

In his 2004 publication, Visual Thinking for Design, Colin Ware highlights that visual perception (the process of seeing and interpreting) involves two types of processes:

- **Bottom-up processing** - driven by the visual information in the pattern of light falling on the retina
- **Top-down processing** - driven by the demands of attention, which in turn are determined by the needs of the task (Ware, 2004, 8).

Bottom-up processing occurs in three main sequential stages: parallel processing; pattern perception and sequential goal-directed processing, as depicted in Figure 2 above. The first stage, parallel processing, involves the extraction of orientation, colour, texture, and movement from our field of vision. This occurs rapidly and without conscious thought. This is why Ware notes that “if we want people to understand information quickly,
we should present it in such a way that it could easily be detected by these large, fast computational systems in the brain” (Ware, 2004, 21). The efficiency of this process is related to the large amount of neurons, up to five billion, which are simultaneously processing different features.

In the second stage of processing, both the working and long-term memory are engaged; partitioning the detected features from stage one into regions and simple groupings or patterns. This stage is influenced by both the information acquired from stage one, as well as from top-down attention-driven inquiry (Ware, 2004). The third and final stage is where a small number of visual objects are distilled through the previous pattern-processing stage. At this level, objects are temporarily stored within the short-term memory for quick recall and processing; however, only a small amount of data can be held in attention at one time (Ware, 2004). This stage is also influenced by goal-oriented processing, based on directed or stimulated questions. “We see something that catches our interest and provokes a question, which we pursue by searching through the patterns in our visual field (a visual query) to satisfy our interests and answer the question” (Few, 2010, 3). Understanding these three stages of visual processing is vital to ensuring that visualizations are designed to be readily and rapidly decoded by the human brain.

Calibrating visualizations for success

Creating effective visualizations involves care and precision. Just like verbal language, visual communication depends on semantics and syntax; it is therefore important to understand the rules in order to communicate effectively (Few, 2007). Edward Tufte’s The Visual Display of Quantitative Information was the first publication of its kind to highlight the difference between graphing data and effectively visualizing it. In this 1983 publication, Tufte highlighted that the majority of individuals using visualization were doing so poorly (Tufte, 1983). Practitioners emphasize the importance of becoming literate in visualization techniques (Lindquist, 2011b).

While there is still debate over certain principles for data visualizations, some rules are general accepted as good practice. Noah Iliinsky, co-author of Designing Data Visualizations, states three general guidelines for strong visualizations. These include: understanding your data; understanding what you want to show; and understanding the format of your visualization and its strengths and limitations (Iliinsky, 2011).

Understanding Your Data

One of the most important dimensions of understanding data is knowing the relationships or patterns in a dataset. Data can be classified as either discrete or continuous. Discrete (or nominal) data represents separate items which have no intrinsic order in relation to one another (e.g., apples and oranges). Continuous data has a particular ordered pattern (e.g., temperatures, days of the week, income brackets, etc.) (Whitney, 2011). Visualization conventions infer that these types of data are displayed differently to ensure that their relationship is easy to identify. For example, if you are representing continuous data which is connected chronologically, forms such as timelines, line graphs, or family trees will help readers quickly acknowledge this relationship. Discrete data on the other hand could be graphed using nominal scales or ordinal scales; for example, a pie chart displaying the percentage of people who prefer apples to oranges.
Further distinctions of data types have been made in recent years, the culmination of which was a 1996 publication by Ben Shneiderman that outlined seven different kinds of data: one-dimensional, two-dimensional, three-dimensional, temporal data, multi-dimensional data, tree data, and network data. While some of these titles provide clues for graphing options, it is also important to identify any patterns within a dataset. Nathan Yau highlights that patterns can be found in aggregates that help you compare groups, people, or things. They can also be derived from observing changes over time, or over geographical regions (Yau, 2011). Understanding the patterns and relationships of the data will also assist in identifying what important data you want to highlight for your reader.

**Understanding What You Want To Show**

The audience and purpose of the visualization should always be top of mind when considering what you want to visualize. Presenting unfiltered entire renderings of datasets, or “visual data-dumps”, is often overwhelming for readers. As one IDRC-supported researcher commented, “the strength of data visualizations come from their appeal and their usability for readers. You often only have 5-to-10 minutes to capture the attention of a policymaker; therefore the visualization needs to have a strong focus” (IDRC Grantee Respondent, 2012). Illinsky and Steele stress the point that it is important to consider the context of your reader including their motivation, level of interest, and the time available (2011). If designing for a broad audience, it is best to identify the most important readers within this group and design for them.

A data visualization should be a stand-alone item, even within a larger report. The data visualization’s title, axis, and choice of data elements should have a clear message that you can understand even without reading the paragraphs of text around it.

As a general principle, it is advisable to keep displays simple and allow a specific narrative to organize the information. Establish hierarchies and use size, colour, and orientation to signal what is the most important data.

All data visualizations fall somewhere along the author-driven to reader-driven spectrum. An author-driven approach displays data in a specific order, includes no interactivity, and has a structured message or narrative. It is essentially like a traditional storytelling structure, where the author controls the speed, order, and information provided. In contrast, a reader-driven approach provides information without a specific narrative. It has no prescribed ordering, includes a high level of interactivity, and has little-to-no messaging (Segel & Heer, 2010). While the author-driven approach is better at providing a specific message to the reader, the latter approach can create a sense of ownership for very interested, engaged, and knowledgeable audiences.

There are three main types of interactive visualizations.

1. *The Martini Glass Structure* provides author-driven display initially (moving up the stem of the glass); once the author’s narrative is
complete, the functionality opens up, enabling readers to interact with the data (the widening mouth offering multiple paths).

2. The Interactive Slideshow uses a regular slideshow format to display data in truncated pieces and enables the reader to explore particular points of interest on each slide before proceeding to the next segment. This is particularly effective for displaying complex datasets since the author can provide step-by-step guidance for the reader, while also designating discrete boundaries between different narrative segments (Segel & Heer, 2010).

3. The last structure is the Drill-Down Story, which provides even more reader-driven exploration. This structure presents a general theme then allows the user to select particular data points to extract further information. While the reader is the one controlling which stories are investigated, the structure still relies on the author to select what stories to and
what details to include for each drill-down item (Segel & Heer, 2010).

**Understanding Form**

In the past couple of years, there has been a dramatic rise in publications highlighting good data visualization practice and providing step-by-step instructions for creating effective charts and graphs. While there are always exceptions to these rules, what is most important for researchers and designers is to understand the strengths and limitations of different formats.

Colour can be a very important tool for setting the tone of the data visualization, or for highlighting certain data points such as outliers. David McCandless has showed the vastly different connotations colours have in different cultures (see Figure 3 on page 6). One IDRC-supported researcher said that during the creation of their data visualization they were careful not to select colours associated with any political party. This example is useful because it reveals that colours hold different meanings across different cultures and contexts.

**IDRC and Data Visualization**

Data visualization is not a new concept for IDRC or its partners. In order to gain a better understanding of how IDRC-supported research has used data visualizations, and to what effect, a three stage analysis was conducted using IDRC-supported research outputs. The first two stages were conducted internally and provide context on the frequency of data visualizations used. Stage 1 provides a snapshot of how often visualizations are used and within what type of documentation, while stage 2 examines what kinds of visualizations are used most often. Stage 3 provides an external assessment of the Centre’s data visualization use; exploring whether these data visualization design follow good practice, and ways of improving data visualization use to ensure effective communication of research findings. The third stage is an expert review of a sample of visualizations that were put forward as strong examples from IDRC-supported research.

**Methodology for stages 1 and 2**

The first stage of this process questioned the degree to which IDRC grantees are currently using data visualizations to communicate their findings. A random sample was collected from all documents filed in IDRC’s Digital Library (IDL) since 2009. A total of 330 documents were examined and coded for their document type and the occurrence of visualizations. (Each document was initially coded for the following: document type, presence of visualizations, presence of tables, visualization category, and number of visualizations.) This sample size provided a confidence level of 95% and a confidence interval of 5. The documents were selected from across the IDL collections, ensuring representation from all programs within the Centre. Overall, the review was composed of:

- 80 academic publications (e.g., journal articles, books, book chapters, literary compositions or dissertations, and scoping or exploratory studies);
- 71 professional publications for the development, policy or general community (e.g., policy briefs, project briefs, manuals, curriculum, and training materials);
- 71 project reports;
- 48 event-related documents (e.g., text of conferences, proceedings, speeches, slide presentations, workshop reports);
- 40 media documents (e.g., website,
social media posts, newsletters, bulletins, pamphlets, newspaper articles, pictures, and videos); and,

- 20 evaluations.

A key limitation of the sample is that documents in the IDL are print, so these outputs do not include dynamic visualizations. To account for this limitation, additional efforts were made to source dynamic data visualizations for inclusion in stage 3.

After initially coding the sample documents from stage 1, all documents which contained data visualizations were separated out for inclusion in stage 2. During stage 2, a second sample of documents were coded to examine what types of visualizations were being used, and further specifications on colours, axis labels, source information, and data clarity, were also noted. In total, 36 documents were selected for inclusion in stage 2. Documents were selected at random, but the number of each document type was calculated from the percentage of visualization occurrence per document type.

To complement the findings of this review process, five IDRC staff members (from programs branch, communications, and information management) participated in structured interviews, which lasted forty-five minutes. As well, over fifteen other staff members reviewed a selection of IDRC-supported research visualizations during an interactive lunch-time session in November 2011. Lastly, three grantees participated in one-on-one phone interviews that provided insights on their experience and reflections on data visualizations.

Review findings

Stages 1 and 2 reveal that IDRC-supported research has invested time and resources in creating data visualizations to present research findings (and continues to do so). Forty-eight percent of sampled IDL documents included some form of data visualization (see Figure 4 above). However, the majority of this visualization-use was focused on the insertion of charts and graphs into publications or presentation slides. There were very few examples of advanced visualizations, and none of the documents demonstrated truly innovative or ground-breaking design use. (While this could in part be linked to the inability of the IDL to capture the more interactive and online displays, there were very few online examples brought forward during stage 3.) Instead, the documents tended to use fairly simple visualizations (line, bar, and/or pie charts) as a way of complementing the textual explanations of the research findings, or to provide a visual representation of models or systems. In total, seventy-two percent of documents with visualizations included these aforementioned chart types, while the remaining twenty-eight percent used other forms which varied from tree maps to Venn-diagrams.
The review also found that not all document types used data visualizations to the same degree (see Figure 5 above). Academic publications had the highest rate of visualization use and contained on average more visualizations per document than any other type. (It should also be noted that academic publications tended to have a higher number of pages per document than other documents, which provides the potential for additional room for the inclusion of data visualizations.) In contrast, media documents included the fewest instances of data visualizations. Most of the media documents reviewed were under ten pages and used map graphics most frequently. For academic publications, line charts were the most frequently used form, compared to bar charts that were most common overall and received the highest rate of use in all other document types. These findings suggest that IDRC-supported research uses visualizations more frequently to communicate to academic audiences rather than communicating to the general public. As noted previously, news outlets are one of the leading users of visualizations; therefore the lack of data visualizations in materials targeted towards this interested and engaged audience is a missed opportunity to bring greater attention to this research.

While it is important to acknowledge which types of visualizations are being most used in research outputs, it is also important to assess whether the forms are being used well. As discussed above, the effectiveness of data visualizations is predicated on proper design and integration. Stages 1 and 2 revealed several broad concerns affecting the integration of data visualizations overall. These concerns were primarily regarding issues of inconsistency, reliance on 3D graphics, and the ineffectual use of text.

Issues of inconsistency were found around the use of colour schemes and charting graphics. Nearly forty percent of documents reviewed in stage 2 included the unjustified use of multiple
colour schemes which shifted from one visualization to another. The most extreme instance of this was a document that used over eight different colour palettes in its different visualizations. If a document changes its colour palette, the effect can be jarring and distracting for readers, since their mind is automatically decoding colour differentiation and searching for implied meaning. In contrast, several other documents used colours extremely effectively, drawing attention to sections of the data being discussed.

The use of different graphics was another area of inconsistency. There were several documents that changed the graphic-bars used within the bar chart to cylinders half way through the document, without justification. Alternatively, other documents would introduce 3D-bars into one chart and 2D-lines in the next. Much like alterations in colour, the mind’s visual processing registers these changes and can misinterpret them as patterns which hold deeper meaning. Good practice recommends that there should be a consistent graphic used for all visualizations of the same form, unless there is a particular reason for deviating from this form.

One of the fundamental principles of data visualization is that the form should be determined by what is being communicated and by the nature of the data. Selecting an appropriate chart form was one of the strengths of the documents reviewed.

Unfortunately, despite the demonstrated competence in determining the appropriate chart form, there were many poor design decisions including the use of 3D-chart graphics. Thirty-eight percent of documents that used bar or pie charts also elected to add 3D graphics. The 3D perspective distorts the overall length of the bars, and misrepresents the surface area of slices.

The final concern that was revealed in stage 2 was the ineffective use of text. The majority of data visualizations were situated within the body of a publication or report without a focused title to help the reader interpret the information being displayed. Stephen Hanks, IDRC’s resident graphic designer, affirms that “headlines and decks can serve as important qualifiers for data visualizations. It can also help readers who are less likely (or comfortable) interpreting the data to have a textual reference to explain what the graphic is showing” (Hanks, 2011). Titles can also play an important role in creating appeal. The benefits of creating focused and compelling titles are numerous, which is why many data visualization proponents advise working with writers to draft supporting texts and headlines.

Overall, these three areas of concern do not suggest the need for extensive reform to data visualization use, but rather refinements and a need for greater education and capacity building around good design practice. The large prevalence of visualizations within the documents sampled indicate that researchers have acknowledged a use, and/or need, for including visual representations of their data. However, as Stephen Few highlights, it is important for this recognition to be coupled with an appreciation and knowledge for appropriate design.

Many of the staff interviewed at IDRC supported the use of data visualization, but felt that it was still an untapped resource, commenting that most of IDRC-supported projects had barely scratched the surface of their potential. One program leader suggested that it should be the programs leading the charge and pushing research partners to attempt new and creative ways of using data visualizations to communicate their research.
Perspectives of IDRC Staff and Partners

When asked to identify reasons that research partners weren’t experimenting with data visualization use, a program officer identified three main rationales from the projects he worked with. First, he felt that there was a general lack of knowledge around how to produce data visualizations. Second, some of the researchers did not see their role as being a communicator, but rather felt their responsibility was to share their work with fellow academics. Lastly, he noted that researchers were becoming increasingly aware of the pedigree and status of international research, and were therefore focused on building accreditation through citation counts instead of producing professional or communication documents. Even for partners who were trying to communicate with audiences outside of academia, there was little attention to the benefits of data visualization. One IDRC-supported grantee commented that it was only recently that they have ‘woken-up’ to the idea of integrating data visualizations to assist with translating their into a format which had greater appeal for policymakers: “Over the last few years we have recognized that when you are presenting data, the data does not necessarily become information… our readers are more interested in getting the information as quickly as possible. They do not want to go through a lot of data to get the information that we want to convey. We have to treat our data so a person with a short attention span can get it... Politicians and bureaucrats have short attention spans. They will devote a couple of minutes to looking at a document, and in that time if there is something that catches their attention, something they can retrain, then they are likely to devote more time” (IDRC grantee respondent, 2012).

Grantees in various regions have also noted that newspapers have been investing and experimenting with data visualizations, creating greater interest and demand for this type of presentation.

Many IDRC-supported grantees already have demonstrated great interest in data visualization, but the grantees who were interviewed also admitted that they had limited knowledge of these tools. One grantee’s communications department highlighted that there is a great divide between the word of the researchers and what the communications departments produce. They emphasized that it was the responsibility of their unit to translate the research into material that is more accessible to a general population. This also included using additional graphics and data visualizations to help make the data more digestible for readers.

Working with designers or communication teams can be one way of strengthening the effectiveness of data visualizations, but it is important that both designers and researchers are in constant communication and clear about the purpose and important take-away messages for the visualization. Also, working with individuals who understand the cultural, social, and political environments can ensure that important design decisions (such as colour choices) are not overlooked. As mentioned above, one grantee recounted that when working with a designer, they were careful not to select the colours corresponding to political parties in the region since the association would likely skew the interpretation of their study’s findings. These strategic choices help ensure that the visualization is well-received by the intended audience, but it is likely that several revisions of the visualization would be needed before it is complete. During IDRC’s 2011 Annual Learning Forum, Enrico Bertini emphasized that it takes several attempts to get a data visualization right; therefore, grantees and IDRC staff should prepare for the time needed to effectively design data visualizations.
It is also important to gauge when it is appropriate to invest in data visualizations and when it is not. One IDRC program staff noted that knowing more about data visualizations also means acknowledging the additional resources (both time and money) that are required to design effectively. He further suggested that partners and IDRC should carefully weigh the benefits of data visualization and employ these tools strategically, not necessarily invest in data visualizations for every output or project. Deciding on what the goal of the visualization would be, and who is the targeted audience, will assist in identifying the utility of the data visualization, and will help partners decide whether it is worth investing the additional resources needed to effectively create a data visualization.

In the final stage of this review process, the Evaluation Unit sought the expertise of an external consultant to evaluate the degree to which data visualizations created by IDRC-supported partners adhere to good design practice. For this stage, Amanda Cox, graphics editor at the New York Times, was brought on board to discuss in richer detail how individual visualizations could be more effective in communicating for influence. Amanda Cox reviewed a total of 21 data visualizations that were gathered from IDRC staff nominations of strong data visualizations created by IDRC-supported partners. Her report is designed to assist learning, using each example to illustrate larger design principles that could be applied to data visualizations across the Centre’s work.

**Conclusion**

The findings from this 3-staged review provided important insights into how IDRC is currently implementing and using data visualizations. One of the largest limitations to section 2 is that it was unable to assess whether the visualizations were in fact effective at capturing the attention, or influencing the actions, of the intended audience. While it was not within the scope of this review to unpack this broader question of influence, it does assess the degree to which IDRC-supported research has used data visualizations effectively to communicate. Assessing appropriate use and design is therefore an important step before evaluating data visualization influence.

This review found that IDRC-supported research is engaging with data visualizations and using them in nearly half of all research outputs. The focus has largely been on standard line, bar, and pie charts over other types of data visualizations. Academic audiences are the most common target audience for IDRC-supported data visualizations since academic publications had the highest rate of use, followed by technical reports. Media documents had the lowest rate of use, which highlights a potential failure to use communication tools that are readily used by newspaper and media outlets.

The data visualizations reviewed indicated that the majority of the designs remain generally clear, but are also generic. There appears to be a lack of understanding about how to tailor design choices to ensure that visualizations are communicating a more focused and compelling message. The review also noted that there is some inconsistency in how full documents are presented (with unjustified changes between colour and graphic choices) which can distract from the flow of the overall document and confuse the reader.

These findings suggest that data visualization use generally remains at a novice level. More attention should be paid to the following three areas to
help improve the effectiveness of the data visualizations currently being created:

- **Document consistency:** coherent colour schemes and chart graphics should be selected and remain through the entire document.
- **Titles and decks:** supporting text should be used to draw attention to the main message or take-away of the visualization.
- **Design choices:** colours, positioning, and size should be carefully incorporated into designs to help draw the reader’s attention to the most important data points.

Refinements in these three areas would significantly strengthen the data visualizations currently produced by IDRC-supported projects, and would help improve their ability to communicate effectively. Many of the staff and grantees interviewed acknowledged that they had a limited understanding of data visualization principles, but demonstrated strong enthusiasm for its potential and a willingness to learn and further engage with these tools. Therefore, they requested further knowledge and skills development around how to strategically use data visualizations.

This report draws attention to some of the basic principles of data visualization, and encourages further conversations amongst IDRC staff and grantees about what resources are required to more effectively communicate using data visualizations. This report is thus only the start of the conversation and provides some initial guidance as to where grantees and IDRC staff can go to acquire further information and support.

As data visualization is likely to grow in importance into the future it is in IDRC’s best interest to continue monitoring data visualization trends and start supporting capacity building of grantees in this area. For years, IDRC has invested in helping IDRC-supported partner’s build their communication abilities by perfecting elevator pitches, policy briefs, media interview techniques, and even PowerPoint presentations. While these skills continue to remain an asset, the rise of the Internet, interactive mobile technologies, and on-going media investments into dynamic visualization platforms signal that this is a new terrain that policymakers, researchers, and practitioners will be expected to master. This does not mean that IDRC should begin to make significant investments into data visualization, but rather that more attention must be paid to refining the data visualizations that are already in use and exploring strategic opportunities to learn or experiment in this exciting new field.

Data visualizations hold great potential for communicating research effectively. IDRC should not be left behind in the data visualization wave, but should be cautious with its investments. After all, the potential of data visualizations can only be realized if we are willing to try, and try again!
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