Technology in Testing

An Introduction to Data Visualization for Testing

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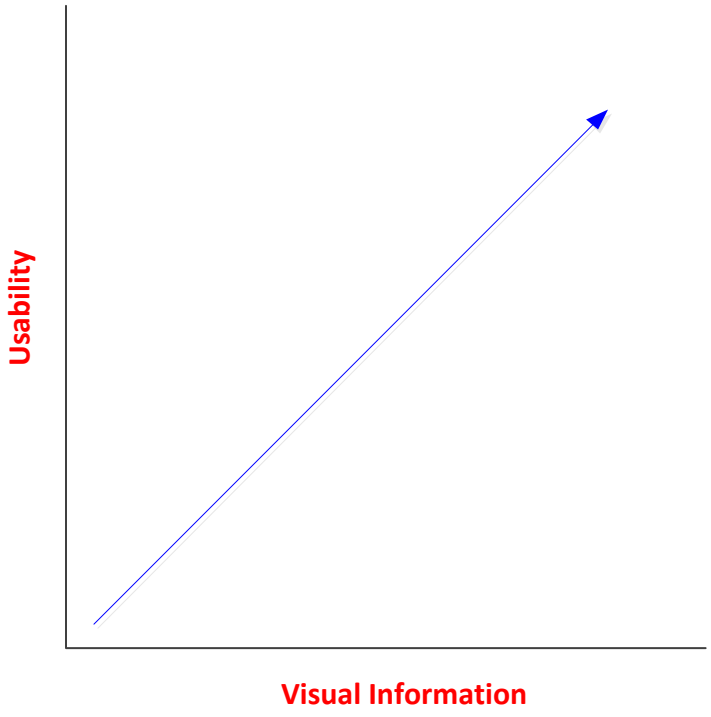
The Gartner Group (2011) has defined data visualization to be "the use of size, color, shape, spatial layout, and textual labels to portray information in insightful ways." Friedman (2008) states, "the main goal of data visualization is to communicate information clearly and effectively through graphical means." In lay person terms, data visualizations are tables, charts, graphs, maps, and other visual tools used to organize data or the results of analyses conducted on the data. To portray data visualization in the language of data visualization

Data Visualization is



Regardless of how you define it, data visualization is an exciting field that has blossomed recently in response to the need to acquire business intelligence from increasingly large datasets. Articles on data

visualization are popping up in the New York Times (Singer, 2011), the Wall Street Journal (Gage, 2013) and most recently in Forbes (Clarke, 2014). New data visualization companies such as Qlik (QLIK) and Tableau (DATA) have entered the marketplace and old companies like IBM, SAS, and Wolfram are marketing new developments to their products in this area.

All of this increased attention has fueled new technology. There are now many new tools available to create data visualizations. A recent article on Future Publishing's CB creative blog describes 36 new tools for creating data visualizations (http://www.creativebloq.com/design-tools/data-visualization-712402). Some of these are small scale freeware while others are enterprise level software developed and maintained by fortune 500 companies. The development pace for these products is fast and furious and the resources available for development are abundant. Taken together, they set the stage for future breakthroughs in data visualization.

Alongside the technology, the science of data visualization has progressed. There are several annual conferences about data visualization. Among these includes the IEEE Vis, Open Vis, and the Eyeo Festival. Many new books have been published from the big names in the industry such as Stephen Few, Noah Illinsky, and Edwin Tufte. And Rice University is now offering a course in their Statistics department entitled Data Visualization.

With all of this excitement about data visualization, one may wonder, "How can we harness this to better testing?" The purpose of this article is to provide a partial answer to this question by identifying areas where data visualizations can be used in testing and by providing an overview of the theory and science of data visualization. Future editions of Technology in Testing will focus other aspects of data visualization as it applies to testing.

Data Visualization in Testing

In testing, data visualizations are most commonly found in digital dashboards, reports, presentations, and occasionally in test items. Of these, I believe that digital dashboards and reports within the testing industry stand to benefit the most from the recent advances in data visualization.

In testing reports, data visualizations are commonly found in examinee score reports and psychometric technical reports. These examples are rather interesting because they differ dramatically. Examinee score reports are seen by many people, often with low quantitative analytic skills, and contain a limited amount of information. On the other hand, psychometric technical reports are seen by very few people, typically with high quantitative analytic skills and contain a large amount of information.

In addition to those two obvious uses, data visualizations are found in a plethora of other reports that are routinely produced in testing. These include but are not limited to job task analysis reports, standard setting reports, item development reports, test administration irregularity reports, jurisdiction performance reports, and training program performance reports.

Some testing organizations are using digital dashboards to help monitor their testing programs. The content of these dashboards varies widely. Some track item production while others track examinee or

psychometric performance. The style and quality of these dashboards also vary. Some are custom applications developed specifically by a test sponsor while others are pre-configured dashboards provided by the major software vendors.

Much of the science of data visualization is focused on the creation of a single data visualization. This science can be directly applied to the creation of the visualizations found in psychometric technical reports or other manually produced reports. On the other hand, digital dashboards bring together the information from more than one data visualization, and the values differ each time the dashboard is loaded. This is also true of examinee score reports, jurisdiction performance reports, and training program performance reports which are typically template driven reports that are populated at run time. Although much of the science of data visualization applies to these, testing professionals may wish to balance their best judgment with the traditional principles of data visualization when designing and implementing template driven reports.

Theories of Data Visualization

Despite the recent advances, data visualization is an old field. Although there were some early pioneers, Edward Tufte was the first person to widely introduce the world to theories of data visualization. Since then, William Cleveland, Stephen Few, Noah Illinsky, Ben Shneiderman, Colin Ware and many others have made notable contributions to the field.

Before briefly describing the theories of these contributors, it is important to put some context on these. The most effective data visualizations (Bontempo, 2012) have the following:

1. 20/20 Purpose – The purpose of the visualization must be clear.
2. Tasty Data – The data used to create the visualization must be accurate, valid, and useful.
3. Chicago Analytics – The analyses must match the purpose of the visualization and the available data.
4. Zen Graphic Design – The graphic design of the data visualization must emphasize the important elements while de-emphasizing the unimportant elements.
5. Euro Interactivity – To the extent possible, users must be able to interact with the data in a manner that fulfills the intended purpose of the visualization.
6. Swiss watch Technological Performance – When data visualizations are rendered on the web, they must load reliably and quickly.

The first element of effective data visualizations stems from Noah Illinsky (2010) who indicated that data visualizations tend to have one of two purposes, to convey information or to promote discovery. In our work with several thousand nursing program educators, Daniel Wilson and I (Bontempo and Wilson 2014) have discovered that data visualization users typically fall into two categories which we refer to as ‘newbies’ and ‘junkies.’ Typically, newbies are interested in applying the findings rather than exploring the data further. For these folks, simple, static visualizations are appropriate. On the other hand, data junkies are interested in gleaning as much information as they can from the data. Typically, they are interested in interactive data visualizations that promote discovery. Since the design of a data

visualization is largely impacted by its audience, it is imperative that data visualization designers develop a clear purpose before proceeding.

Although it is out of the scope of this article to discuss the merits of testing data and analytics, it is pertinent to discuss how the data and analytics relate to the graphic design. Edwin Tufte has contributed a great deal to this aspect of data visualization. Tufte introduced three concepts which are defined below.

- Lie Factor = Size of effect in graphic / Size of effect in data
- Data Ink Ratio = Data ink / Total ink used in graphic
- Chart junk refers to all of the visual elements in charts and graphs that are not necessary or distract the viewer from the pertinent information.

Tufte advocated for truth in science by promoting a Lie Factor equal to one in all data visualizations. Those with a lie factor different than one distort the truth and are discouraged for all applications in testing. Tufte's second contribution was to emphasize the need for a visualization to maximize their data ink ratio and minimize their chart junk. By doing so, the visualization brings attention to the data and findings while de-emphasizing all other aspects of the visualization. In testing, chart junk typically takes the form of legends and gridlines, the impact of which is illustrated below.

Figure 2. Impact of Data Ink Ratio on Data Visualization – High Data Ink Ratio

	2012		2013		**Grand Total**	
Exam	Number of Test Sessions	Mean Scaled Score	Number of Test Sessions	Mean Scaled Score	**Number of Test Sessions**	**Mean Scaled Score**
Content Development	497	112	607	112	**2,743**	**112**
Monitoring and Evaluation	10,050	66	4,782	65	**32,683**	**68**
Program Design	2,586	102	2,614	102	**15,899**	**100**
Psychometrics	2,061	105	2,038	104	**12,807**	**105**
Test Administration	2,250	102	2,245	101	**11,542**	**103**
Grand Total	**17,444**	**82**	**12,286**	**88**	**75,674**	**88**

Figure 3. Impact of Data Ink Ratio on Data Visualization – Low Data Ink Ratio

	2012		2013		**Grand Total**	
Exam	Number of Test Sessions	Mean Scaled Score	Number of Test Sessions	Mean Scaled Score	**Number of Test Sessions**	**Mean Scaled Score**
Content Development	497	112	607	112	**2,743**	**112**
Monitoring and Evaluation	10,050	66	4,782	65	**32,683**	**68**
Program Design	2,586	102	2,614	102	**15,899**	**100**

Psychometrics	2,061	105	2,038	104	**12,807**	**105**
Test Administration	2,250	102	2,245	101	**11,542**	**103**
Grand Total	**17,444**	**82**	**12,286**	**88**	**75,674**	**88**

Colin Ware's contributions to data visualization (2000) focus on using the graphic design components of a visualization to maximize the use of the human brain's pre-attentive processing capacities and minimize the use of attentive processing. By doing so, the efficiency at which the visualization's information is processed is increased. Essentially, this makes findings "pop" off of the page.

Ware identified several ways to effectively represent categorical data through graphic design. These include, color (hue), position, shape, fill pattern, line style, font, sort order, and orientation. Continuous data can be represented in the following ways size, color (saturation, lightness/darkness), and position.

Building interactivity into data visualizations is a relatively new idea. The forms of interactivity most commonly used are data filtering using a check box, radio button, or hot spot, mouse over pop-ups, mouse-over highlighting, panning/rotating, or zooming of which the data filtering is the commonly used interactivity in testing. Ben Shneiderman (Shneiderman and Plaisant 2009) provides the most substantial theory on building effective interactivity although his work is more general covering interactivity in computing rather than interactivity specific to data visualization. Shneiderman has eight golden rules for interactivity which are listed below.

1. Strive for consistency
2. Enable frequent users to use shortcuts
3. Offer informative feedback
4. Design dialog to yield closure
5. Offer simple error handling
6. Permit easy reversal of actions
7. Support internal locus of control
8. Reduce short-term memory load

Although all eight apply to interactivity within data visualization, striving for consistency may be the most important rule. In testing, interactivity can be enhanced by focusing on making the graphic design more consistent. Ways to accomplish this include using consistent names for terms and consistent options within check boxes.

The final element of effective data visualizations may seem obvious, but its importance cannot be understated. Even the most effective data visualization will fail to fulfill its purpose if the website or software rendering it, fails to display the visualization or fails to display it quickly enough to keep up with the short attention span of users today. This point is particularly important with novel data visualizations which utilize custom software to render. These visualizations are most susceptible to hardware and software glitches. This should not stop designers from developing novel visualizations. Rather, designers should dedicate resources to evaluating the performance of computer-based data visualizations before

releasing them to their intended audience. On the other hand, there may be other situations where data visualizations can and should be rendered using traditional tools since the stability of these tools is predictable.

Concluding Remarks

This article provided a brief overview of the exciting new science of data visualization and its application to testing. Licensure organizations providing tests are encouraged to use the information contained within to design, evaluate, and improve their dashboards and reports.

Since the testing industry excels in data analytics, testing organizations are encouraged to focus their improvement efforts in the areas of graphic design and interactivity. The tips provided by Ware and Tufte will go a long way in helping your staff members make simple MS-Excel tables and charts more informative for users. In addition, organizations are encouraged to investigate the landscape of new technological solutions available for interactive visualization and to begin considering where and how to incorporate these into their dashboards and reports.

Future editions of Technology in Testing will continue to address the theme of data visualization. The following topics are anticipated: data visualization design, novel inventions in data visualization, designing data visualizations for digital dashboards, designing data visualizations for testing reports, designing examinee score reports.

References

Bontempo, B. & Wilson, D. (2014). *Innovating Testing Reports with Data Visualization*. A presentation at the Annual ATP Innovations in Testing Conference in Phoenix, AZ, March 3, 2014.

Bontempo, B. (2012). *Data Visualization*. A presentation at the Annual Meeting of the Association of Test Publishers in Palm Springs, CA, February 29, 2012.

Clark, D. (2014). Data Visualization Is The Future - Here's Why. www.forbes.com

Friedman, V. (2008). *Data Visualization and Infographics*. Graphics, Monday Inspiration, January 14th, 2008.

Gage, D. (2013). Pictures Make Sense of Big Data. http://online.wsj.com

Illinsky, N. (2010). *On Beauty*. In N. Illinsky and J. Steele (Eds.), Beautiful Visualization. Canada: O'Reilly Media.

Shneiderman, B. & Plaisant, C. (2009). Designing the User Interface: Strategies for Effective Human-Computer Interaction (5th ed.). Reading, MA: Addison-Wesley.

Singer, N. (2011). When the Data Struts Its Stuff. www.nytimes.com.

Tufte, E. (2001). The Visual Display of Quantitative Information (2nd ed.). Cheshire, CT: Graphics Press.

Tufte, E. (2001). Envisioning Information (2nd ed.). Cheshire, CT: Graphics Press.

Ware, C. (2000). Information Visualization Perception for Design. San Francisco: Morgan Kaufmann Publishers.