2022

Mary Eleanor Spear's Importance to the History of Statistical Visualization

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Submitted to
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for
Senior Thesis
Spring 2022
April 25, 2022

This paper is dedicated to female contributors in male-dominated STEM fields who did not receive the proper credit or publicity.

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Abstract

This paper will demonstrate why Mary Eleanor Spear (1897-1986) is an important figure in the history of statistical visualization. She lead an impressive career working in the federal government as a data analyst before "data analyst" became a thing. She wrote and illustrated two comprehensive textbooks which furthered the art of statistical visualization. Her textbooks cover extensive graphing knowledge still valuable to statisticians and viewers today. Most notable of her works is her development of the box plot. In addition to Spear's career and contributions, this paper will also address the lack of female representation in science, technology, engineering, and math (STEM) fields then and now. There are only very limited sources on Spear's life. Thus, the greater purpose of this paper is to uplift a woman in STEM and to share her story.

Introduction

Mary Eleanor Spear (1897-1986) was a draftsman, statistician and data analyst. Despite Spear's valuable contributions to statistical processes and data visualizations in the mid-1900s and her years spent working for the government as a data analyst, she was not well known in her lifetime and has only begun to receive wider recognition in the past three years. Though Spear was the first to present data in a box plot, this innovative visualization technique was credited to a man who only began using it many decades later (Jones, "Credit Where Credit is Due"; Weisstein). Time and time again contributors in STEM (Science, Technology, Engineering, and Math) fields, especially female contributors, have faced sexual discrimination and have been omitted from history (Western Governors University). According to Ben Jones—founder and CEO of an education company focused on teaching the language of data and professor of data visualization at the University of Washington—in the case of Spear and other women in STEM, their contributions have been attributed to men (Jones, "Credit Where Credit is Due"; Guo). Through this paper, a quiet voice is amplified in attempt to inform readers and to contribute to the history of female statisticians.

First, this paper will provide a biography of Spear, covering her upbringing, college experience, and work experience. Next is a section about female scientists, or lack thereof, in the federal government. Then, this paper will cover her two works titled *Charting Statistics* and *Practical Charting Techniques*, with particular attention to their valuable contributions to statistics such as prototypes of the box plot, data visualization strategies, and charting pitfalls. These sections will include information to how Spear's work is still applies to life today. The paper will conclude with a consideration of Spear's reception as captured in reviews of her work and a call to action for readers.

Biography

Mary Eleanor Hunt was born in 1897 in Indiana to Amos and Mabel Hunt. At the age of three, she moved to live in Washington, D.C. She attended Eastern High School then went to college at Strayer's Business College. She continued her studies at George Washington University in Washington, D.C. focusing on graphic analysis work (*Who's Who of American Women* 1143). Spear would have quite an impressive resume boasting over 30 years of experience working as a visual information specialist and graphic analyst for the federal government. At twenty-two years old, Spear worked as a draftsman living in Washington, D.C. as an employee of the Internal Revenue Service, a division of the federal government responsible for collecting taxes and enforcing the federal statutory tax law (*Internal Revenue Service*; "Suspension Pantograph in Case"). Her role as a draftsman entailed drafting charts of economic data (Jones, "Credit Where Credit is Due"). By 1921, at age twenty-four, she married Albert Spear. Eight years later they had a son, named James Hunt Spear. The Spear family lived together in Takoma Park which is a suburb of Washington in the Washington metropolitan area. During this time she also worked as an instructor and lecturer of Graphic Representation of Statistics at the American University in Washington, D.C.., Government and Labor Workshops, and even taught at The Pentagon for a total of fifteen years (Spear, *Practical Charting Techniques*). By 1934, at age thirty-seven, Spear began work as a draftsman for the U.S. Department of Labor ("Suspension Pantograph in Case"). By 1940, Spear worked at the U.S. Department of Labor under the position title "Analyst" according the U.S. Census (*Ancestry*). From 1948 to 1951, Spear worked under the title "Economic Illustrator" for Office of Publications within the Bureau of Labor Statistics of the U.S. Department of Labor. Her graphs were published and featured in federal governments articles in addition to numerous magazines, books, and periodicals including the NEA-DAVI, Audio-Visual Instruction, Educational Screen, & Guide (Spear, *Practical Charting Techniques*). In 1952, she published her first textbook titled *Charting Statistics*. That same year, she earned the title of "visual information specialist" working for the Office of Statistical Standards within the Bureau of Labor Statistics of the U.S. Department of Labor (Arribas). She published her second and final textbook titled *Practical Charting Techniques* in 1969. At the height of her career, her pay was 6,940 dollars which would be 67,000 in today's dollars (Jones, "Credit Where Credit is Due"; "CPI Inflation Calculator"). Keep in mind that this may have been less pay than her male counterparts. According to the Women's Bureau of the U.S. Department of Labor, three years later in 1955, women on average made about sixty-four percent of men's salary income. Even within the occupation category called professional and technical workers in 1969, women on average still made about sixty-four percent of men's salary income (U.S. Department of Labor, 1-2).

During her career, she operated her own studio in which she drew beautiful charts and statistical visualizations by hand using various techniques and tools such as a pantograph (Arribas). A pantograph is used to create an enlarged or minimized copy of an illustration by adjusting knobs to the desired size. Spear's pantograph, below, is preserved at the Smithsonian National Museum of American History (see fig. 1).

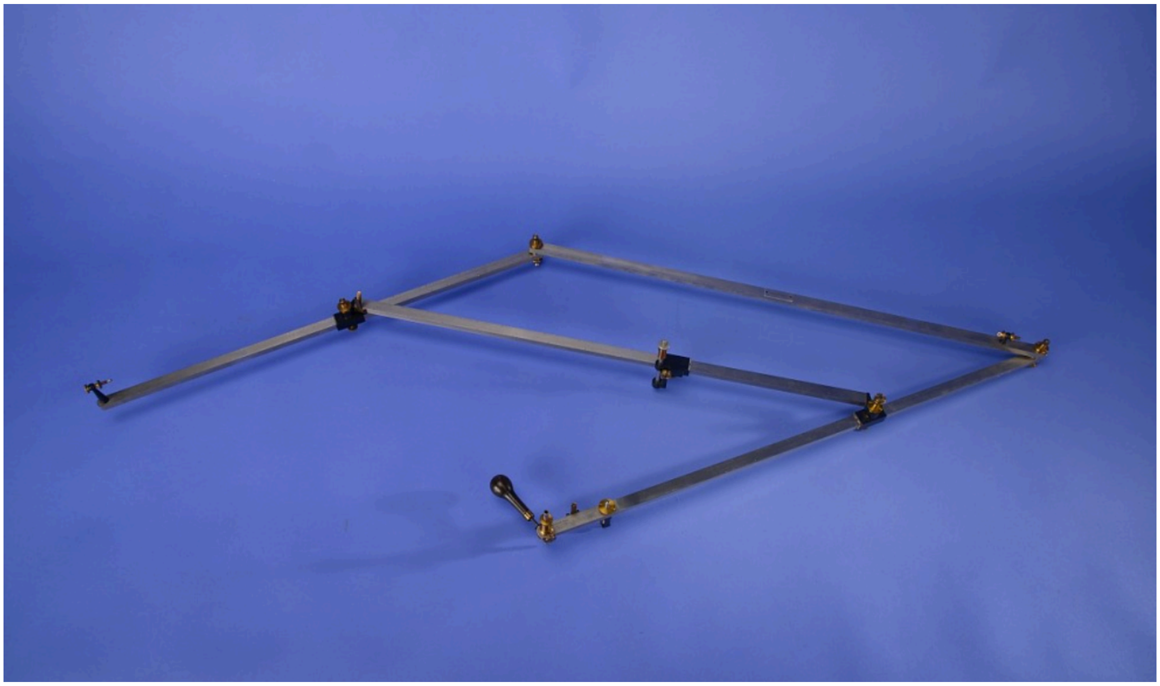

Fig. 1. "Suspension Pantograph in Case by G. Coradi of Zurich Sold by Eugene Dietzgen Company with Stand." *National Museum of American History*, americanhistory.si.edu/ collections/search/object/nmah_904630.

According to Spear's granddaughter, Spear set up a drafting room in the house with the drafting table taking up nearly half of the room hugged by stools for her grandchildren to watch her work her magic (Jones, "Credit Where Credit is Due"). Spear was "very devoted to her craft" and conception of visualizations which helped further her career (Jones, "Credit Where Credit is Due"). Spear went from draftsman to analyst to economic illustrator to visual information specialist. With these odd position titles and lack of a division for data science, it is fair to say that Spear had an impressive career in data visualization before “data visualization” became a thing. Although her works were published decades ago, they are still relevant today. Spear had long, successful careers and she taught many people about the art of data visualization before passing away in 1986 in Maryland at 88 years old (*Ancestry*).

Female Scientists in the Federal Government

Spear’s expansive career working for the federal government was unique to her gender. She was an anomaly in the male-dominated field of statistics. Spear was a teenager at the time of World War I, an event which completely altered the work force. Women working in the federal government were typically held to clerical or typing positions before the war. However, the onset of the war spurred the need for trained office personnel and pushed aside restrictions against women. This change opened up thousands of jobs for women (Rossiter 219). Feminist reforms in the 1920s and 1930s did little to change the patterns of “sex-segregated employment” (Rossiter 222). Although there were more positions for women in the government as a result of these reforms, these positions were still relatively low-level or typically deemed “womanly” such as working in home economics. The *American Men of Science*—a biographical directory of leading scientists in the United States and Canada renamed *American Men and Women of Science* in 1971—found that there were only twenty-nine and one-half female scientists in federal agencies in 1921 (“American Men & Women of Science”; Rossiter, *Women Scientists in America* 222). This reference does not clearly explain what it means for half of a woman to work here. That one-half was the number of women working for the Bureau of Labor

Statistics, where Spear would work as a statistician a few decades later (Rossiter, *Women Scientists in America* 221). This number grew slowly. In 1925, according to *The Status of Women in the Government Service*, there were only eighty-seven female scientists in federal agencies. Even in 1938, less than five percent of women working in the federal government were working in STEM fields, and, of that small percentage, only a few performed science-rated jobs. In fact, there were eighty-five female statisticians and mathematicians in the federal government by the late 1930s, making up less than ten percent of all statisticians and mathematicians (Rossiter, *Women Scientists in America* 222). Spear was one of these women who worked to overcome the widespread sexual discrimination (Rossiter, “Women Scientists in America before 1920” 312). Despite the gendering of the workforce, Spear did not let gender discriminatory practices stop her from becoming a distinguished statistician.

Spear’s Textbooks

In order to understand Spear's contributions to the representation of data, I will consider select contents from her two textbooks: *Charting Statistics* and *Practical Charting Techniques*. Spear crafted most of the statistical illustrations of the textbooks while some of the visuals were sourced from her work in the government. Note that the text and illustrations in *Practical Charting Techniques* is partly derived from *Charting Statistics*. In the preface of both of her books, Spear states that the purpose of the text is to teach “all those who are interested in presenting a visual message” to all audiences whether it be specialized groups of people or the general public, teachers or students (Spear, *Charting Statistics* 3). These texts, which are each a few hundred of pages, cover graphic presentation, planning charts, tips for implementing charts, and visuals of different types of charts. They are rich with advice from Spear whether it be how to format the axes of histogram or common mistakes when using pie charts. Spear illustrates her texts with examples from her work and publications for the federal government and reimagines real-life economic problems encountered during her career (Spear, *Charting Statistics* 3; Spear, *Practical Charting Techniques* vi). Here I will focus on are the range bar, graphic presentation techniques, and charting pitfalls.

Spear's Development of the Box Plot

Kenneth W. Haemer, former presentation research manager at AT&T, was the first to term this type of chart a "range-bar" in 1948 in *The American Statistician* (Haemer 23) (see fig. 2).

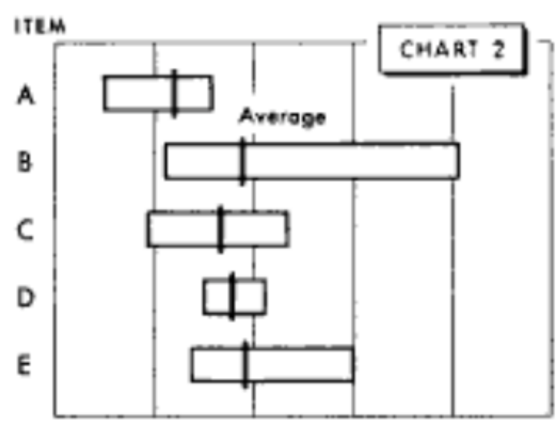

Fig. 2. Haemer, Kenneth W. "Range-Bar Charts." *The American Statistician*, vol. 2, no. 2, 1948, pp. 23. *JSTOR*, doi:10.2307/2682234.

Inspired by Haemer, Spear presented her version of the range bar but with an interquartile range, shown below (see fig. 3). This visualization later became what statisticians now know as the box plot. She defines the range bar as a chart with "gives[s] a simple visual comparison" which "show[s] the range relationship of each item" (Spear, *Charting Statistics* 164).

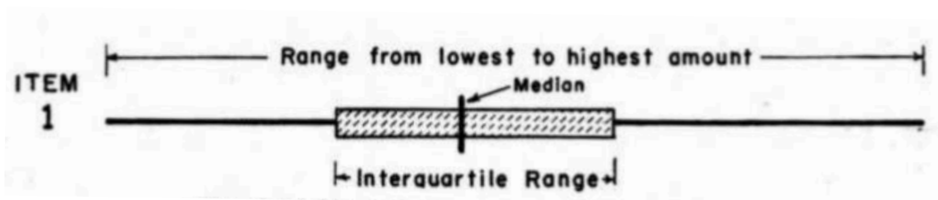

Fig. 3. Spear, Mary Eleanor. *Charting Statistics*. McGraw-Hill, 1952, pp. 166.

This is the representation which was later adapted and named the box plot or the box-and-whisker plot. This method of plotting and presenting data points is still widely used by statisticians today. Despite this development, Spear's work was overshadowed by American mathematician and statistician John Tukey's box plot displayed below (Arribas). This figure is from Tukey's text titled *Exploratory Data Analysis* published in 1977, which is 25 years later than Spear published her variety of range bars in *Charting Statistics* (see fig. 4).

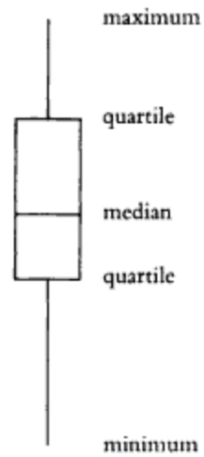

Fig. 4. Tukey, John W. “Easy Summaries--Numerical and Graphical.” *Exploratory Data Analysis*, by John W. Tukey, Addison-Wesley, 1977, pp. 38–41.

His version of the box plot is strikingly similar to Spear’s rendition. Tukey’s box plot is essentially Spear’s interquartile range bar turned on its side with simpler labeling. However, as Tukey did not cite Spear's work, or any work for that matter, he subsequently received credit for inventing the box plot (Friendly, 23).

Spear’s work in statistical visualization and data analysis is still influential today. Her range bar now commonly referred to as the box plot has been transformed and employed in a variety of ways. Like many developments in STEM fields, the box plot has gone through multiple iterations throughout the years. Tufte, a renowned American statistician and professor at Yale University, drew up prototypes of a simplified box plot in his book titled “Data-Ink Maximization and Graphical Design” (Deep). The purpose of Tufte’s book is to convey the necessary information of graphs while maximizing the ink used to present such information in order to be as concise as possible. One of Tufte’s box plot data-ink-maximizing prototypes is shown below, with the offset lines representing the interquartile range (IQR) (see fig 5). Labels have been added for clarity.

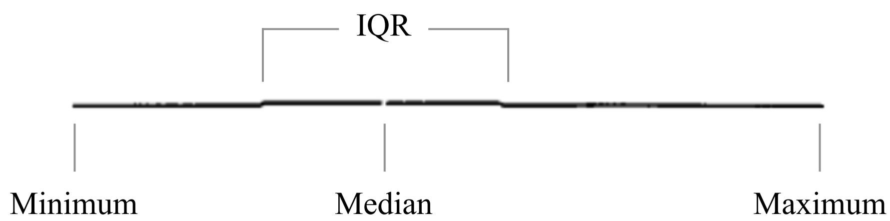

Fig. 5. Tufte, E. R. "Data-Ink Maximization and Graphical Design." *Oikos*, vol. 58, no. 2, 1990, pp. 131. *JSTOR*, doi:10.2307/3545420.

Modern-day Use of the Box Plot

The box plot is a useful chart for displaying metrics of various disciplines today. For instance, the NASA Task Load Index (TLX) is a "subjective workload assessment tool which allows users to perform subjective workload assessments on operator(s) working with various human-machine interface systems" ("NASA TLX"). This tool, originally developed by NASA Ames Researcher Sandra Hart as a physical questionnaire, has "become the gold standard for measuring subjective workload across a wide range of applications" ("NASA TLX"). The tool determines the mental workload of participants while they perform specific tasks ("NASA Task Load Index"). The results of these findings are often presented in a box plot. For example, in the figure below, the mental demand of participants' English and Chinese speech and keyboard scores are plotted. This display effectively shows that the mental demand of using an English Keyboard is lower than the mental demand of using a Chinese keyboard. Likewise, the mental demand of speaking English is lower than the mental demand of speaking Chinese (“NASA TLX Load Index.”) (see fig. 6).

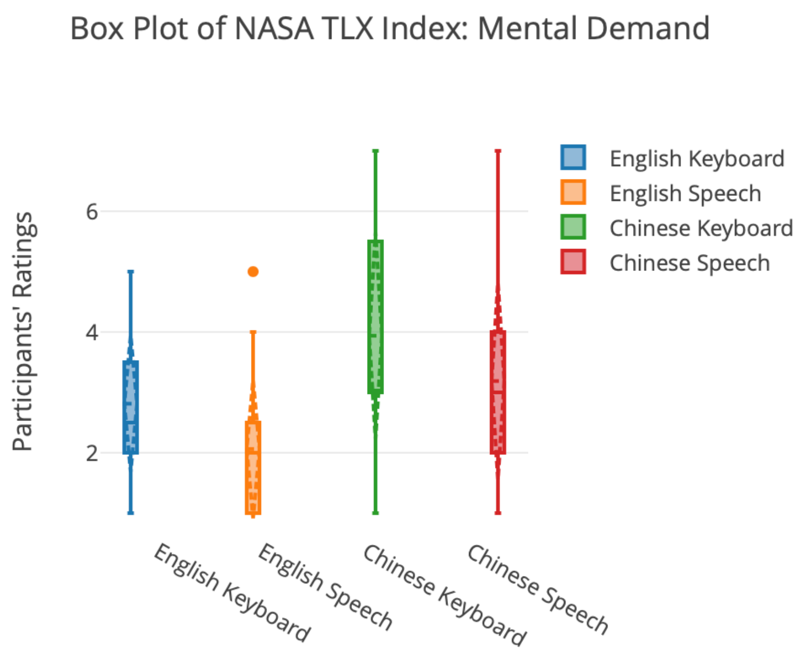

Fig. 6. “NASA TLX Load Index.” *Input Study*, 2018, hci.stanford.edu/research/speech/plot_NASA.html.

Graphic Presentation

Both *Charting Statistics* and *Practical Charting Techniques* begin with a section on graphic presentation which covers the art of selecting the type of chart, designing the chart, and the roles of communicators, graphic analysts, and draftsmen. According to Spear, a draftsman and graphic analyst herself, there are three key pieces of knowledge for each of these roles. The graphic analyst, for instance, must advise the communicator on the type of chart, the choice of media, and the preparation of data (Spear, *Practical*

Charting Techniques 7-12). Then the draftsman must know what materials to use, what size to make the visuals, and the deadline of the project (Spear, *Practical Charting Techniques* 14).

Spear also shares some insights for choosing the correct graph. Ideally, the graph would reveal the message behind the words and numbers “briefly and simply” (Spear, *Charting Statistics* 3). “A good graphic presentation has only one interpretation” (Spear, *Practical Charting Techniques 2*). And, finally, the viewers’ first impressions are extremely important and so is effectively conveying one’s message. Although Spear’s techniques of producing graphs by hand are outdated, graphing tips such as these are still relevant to data analysts and statisticians.

Cheating By Charting

The “Cheating by Charting” section is one of the most referenced and acclaimed sections in Spear’s *Practical Charting Techniques*. This section covers common distortions and illusions of statistic visuals. These altercations can mislead audience and exaggerate the story of the data. One common way graphs are distorted is by expanding and contracting the axes as shown in the visuals below (Spear, *Practical Charting Techniques* 55) (see fig. 7).

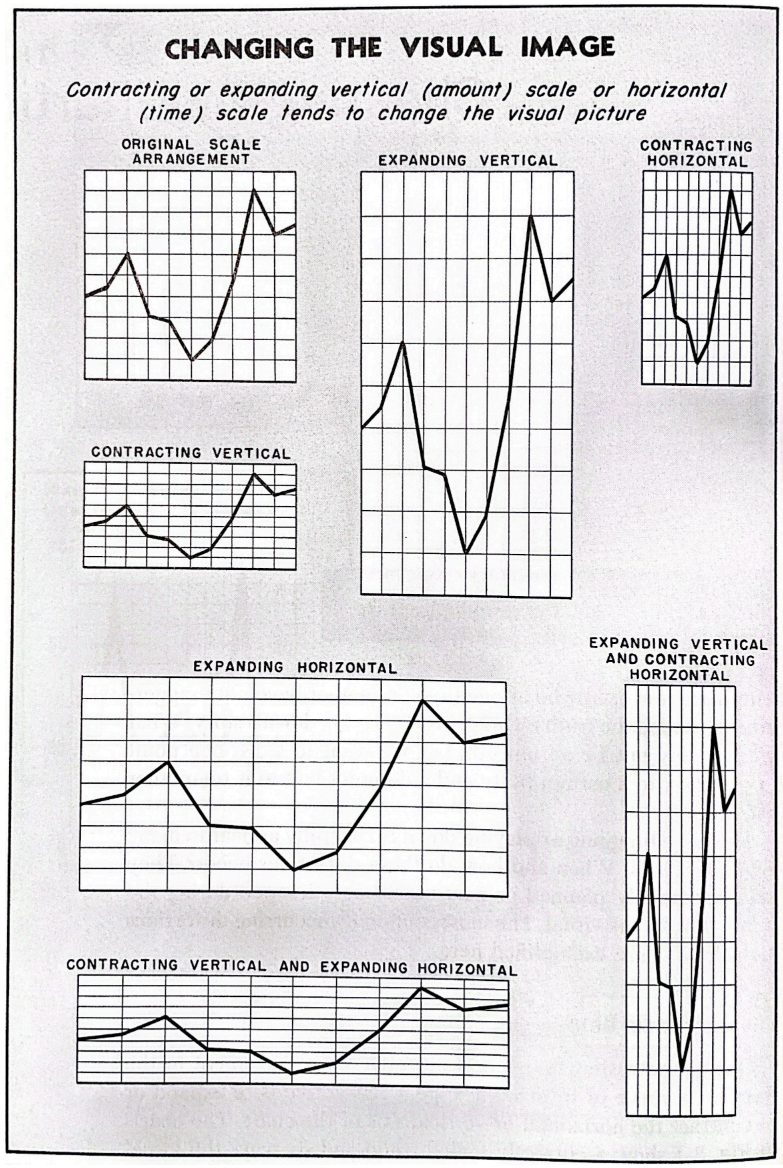

Fig. 7. Spear, Mary Eleanor. *Practical Charting Techniques*. McGraw-Hill, 1969, pp. 56.

Another way to exaggerate one's story by graphing is skipping the grid and "fudging […] with the time scale" (Spear, *Practical Charting Techniques* 57).

Spear provides her own illustrations coupled with more examples of graphing pitfalls. These include not starting the y-axis metric at zero, breaking grids, and having tricky indexes. Spear also advises against using pictographs, maps, and three-dimensional charts to represent data as they can often be misleading. Pictographs and maps are difficult to measure the area by simply looking at them while three-dimensional charts are difficult to interpret and make comparisons (Spear, *Practical Charting Techniques* 62). The section concludes with visuals of optical illusions to watch out for. For instance, viewers tend to see vertical lines as longer than horizontal lines. In addition, shapes with wider borders tend to look smaller than shapes with thinner borders. Spear emphasizes that “visual presentations have a more lasting impression” than the relative statistics they represent (Spear, *Practical Charting Techniques* 68).

Spear’s “Cheating by Charting” section covering the misinformation by graphs is useful for statisticians and data analysts as well as viewers today. Statistical visualizations are powerful, but they can be used to stretch the truth purposely or accidentally which misleads viewers. Misleading graphs are still present throughout news and media today in order to push agendas or, as Spear noted, “to stress one point […] to a certain party” (Glen; Spear, *Practical Charting Techniques* 55). It is important as a data analyst to know the common ways to cheat by charting in order to avoid unintentionally misleading the audience. It is also important as a viewer to know the common graph distortions in order to be a more educated and critical consumer of media. In an increasingly data-driven world, it is becoming increasingly valuable to know how to read charts, infographics, and diagrams, and to know when these are trying to deceive. Contemporary textbooks on data visualizations have similar discussions. “How Charts Lie”, “How to Lie With Statistics”, and “Calling Bullshit” are just a few examples of modern-day books tackling these same issues.

Reception of Spear's Texts

Spear's texts received positive reviews. Benjamin R. Blankenship, Jr., research journalist of the U.S. Department of Agriculture, reviewed the text saying, "if you really want to know how to make an acceptable chart, buy this book" (Blakenship, 270). His favorite part of *Practical Charting Techniques* is the "Cheating by Charting" section which had excellent examples of charts. He critiqued the work, however, for not mentioning which cases graphs would help or harm your presentation or how graphic analysis can provide answers. Looking ahead, he stated, "not even mentioned is the real comer of the business, automatic data plotting by computer" (Blakenship, 270). Overall, Blakenship recommends the book and says readers have more to learn more about charts from it. Another review by Irving Roshwalb left positive remarks saying the book was well-written and useful citing helpful graphing examples. Roshwalb also found it interesting that there was a section on the preparation of charts for television presentations. He criticized the work for not including more information about how to create the graphs by hand. Although it is more the job of a draftsman than the graphical analyst for that kind of work, it would be useful knowledge according to him. Coming from a journalist and marketer, both reviewers praised the text for being easy to understand for non-statisticians.

Conclusion

Spear is an important statistician, analyst, draftsman and educator. She taught people of all audiences about how to best tell stories through data and her insights are still relevant today as data and statistical visualizations are becoming more popular. Spear has also contributed to the development of statistical visualizations such as the box plot which has been used in across a wide range of disciplines. Spear shared valuable lessons in her textbooks, learned from her years of working for the federal government. Her insights on how graphs can mislead viewers are incredibly relevant today as people are bombarded with advertisements, news, and social media posts with quick statistics. Time and time again, graphs are used to convey messages which may or may not be truthful. By distorting graphs, statisticians can mislead viewers. Thus, viewers must arm themselves with the knowledge of how to see through these distorted graphs in order to form educated opinions.

Despite gender discriminatory practices, Spear led an impressive career in STEM. As a female data analyst and math major myself, I know that sexual discrimination exists in STEM fields as I have witnessed it personally and among my female colleagues. People of all genders must be on guard against sexual discriminatory practices such as pay disparity, pushing women toward more “womanly” jobs, and even attributing women’s innovations to men. Some major contributions to STEM fields that were made by women but attributed to men include the first model of nuclear fission, the early prototypes of computer programing and algorithms, and the discovery of the double helix in DNA (Ratherford-Morrison). Gender discriminatory practices are still present throughout STEM fields today. For instance, the gender pay gap within STEM jobs is still an issue despite the growing increase of women in STEM (Fry et al.). Improving the gender pay gap begins with ending exclusion practices and improving female representation. Women today are driven away from the more “manly” jobs such as computing and engineering jobs while being overrepresented in the more “womanly” health-related jobs (Fry et al.). In fact, girls’ disinterest in STEM fields begins as early as childhood as they are pushed towards more care-oriented work (“Women in STEM”). To combat this, measures must be taken by authority figures beginning with parents. It is important for children, regardless of their gender, to know that they can be anything they want. Educators and schools can implement Female-focused organizations and events which encourage women to pursue STEM. They can also offer grants and scholarships for women as well as to fight against sexual discrimination to improve retention (“Women in STEM”). By knocking down gender barriers, we can improve female representation in STEM and work to close the gender gap. These are pervasive societal sexual discriminatory practices which we must all work to counteract. Acts to counteract these sexual discriminatory practices may be something as simple as encouraging your friend when she is struggling with her math homework or standing up for a female coworker in a board meeting. Change starts with you.

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