100 years of Pies vs. Bars

William Playfair introduced the pie and bar charts in the early 1800s, and by the turn of the next century, strong opinions about the effectiveness of alternative displays of the same data had been publicized in textbooks and manuals. For instance, Eells (1926) quotes two contemporary resources which discuss pie charts as "not a desirable form of presentation" (Brinton 1914) and more strongly, "an insult to a man's intelligence" (Karsten 1923). Brinton (1914) even identifies that the "sector method" is common, but if horizontal bar methods were used more frequently, they would be preferred for both speed and accuracy. Eells (1926) also quotes an excerpt from an introductory statistics textbook (Secrist 1925), which argues that pie charts require more cognitive effort to use accurately than a comparable stacked bar chart, calling pie diagrams "clumsy and defective". These insights mirror today's status quo: pie charts are stubbornly common, even though many design guidelines recommend against their use and a variety of empirical studies identify problems with circular data representations . Wickham (2013) previously noted the prescience of design guidelines prior to empirical studies validating their recommendations across different types of visualizations.

The Dawn of Empirical Graphics

Interestingly, the question of pies and bars motivated some of the first empirical evaluations of charts, published in the Journal of the American Statistical Association: Eells (1926), von Huhn (1927), and Croxton and Stryker (1927). Experimenters approached the problem head-on, directly asking participants to estimate quantities from charts, and evaluated participants on accuracy, and in some cases, speed. While more sophisticated testing methodologies have been developed over the past century (Vanderplas, Cook, and Hofmann 2020), studies are still conducted today using direct estimation approaches (VanderPlas, Ryan, and Hofmann 2019). Now as then, the phrasing of direct estimation questions is of primary importance: a simple mathematical transformation of the estimated quantity can have an outsized effect on the results.

The initial studies of the question of pies and bars failed to identify a clear "best chart" across all situations, or even to clearly identify in which situations pie charts or bar charts should be preferred. Eells (1926) found that pie charts were read as accurately as bar charts and with comparable speed. The simplified nature of the experiment attracted critiques from von Huhn (1927); attached to these criticisms is a short study previously run by Croxton which examined estimates of the ratio between smaller and larger sectors of two-category pie and bar charts; these contributions will be addressed separately even though they are often cited as a single paper, even within the JASA records. von Huhn (1927)'s paper provides several examples which highlight concerns with the Eells study, and argues that while pie charts may be better in certain simple situations, bar charts are much more extensible and facilitate more advanced comparisons, but does not include any experimental studies. Croxton's early experimental data (attached to von Huhn (1927)) had a larger number of participants than Eells (1926), but only tested two-category charts with only two proportions: .25 and .4. In addition, Croxton's study elicited estimates from participants as A/B comparisons, where $A+B = 1$, while Eells elicited estimates for A and B separately. This multi-year back-and-forth conversation is interesting in part because it pinpoints an early example of experimental statistical graphics as a discipline of interest to statisticians for both personal investigation and as an audience for the results.

Subsequently, Croxton and Stryker (1927) published additional data assessing accuracy of estimates from pie and bar charts, varying number of categories and orientation/alignment of sections. Croxton and Stryker (1927) found that pie charts matched or surpassed bar charts in most situations, across different scale alignment and in charts with up to 5 categories (though at 5 categories, differences were not statistically significant). The final paper in this early set of comparisons was Croxton and Stein (1932), which examined a variety of representations of proportional data, but outside the context of a statistical chart; the experimental stimuli, while applicable to charts, show a focus on general perception (though published in JASA).

Experimental graphics studies seem to have largely gone unreported (if they were conducted) between 1932 and the 1980s, particularly in statistical publications, though the issue of pies and bars occasionally pops up during this period in other disciplines.

Modern Experimental Graphics

Much later, Cleveland and McGill (1984), a statistician and a psychologist by training, respectively, conducted experiments on simple graphical elements. These experiments were presented as supporting a hierarchy of graphical perception which evolved over the course of the sequence of studies. This ranking indicates that aligned length judgments are more accurate than judgments based on area or angle, with the impli-

cation that bar charts are more accurately perceived than pie charts. While the full hierarchy of feature comprehension is often assumed to be experimentally derived, the experiments presented in the series of Cleveland & McGill papers only inform a few elements of this hierarchy. As in the late 1920s, the combination of introspection based reasoning and a sequence of simple experiments did not go uncontested. Spence and Lewandowsky (1991) (both psychologists) used forced-choice questions of the form "which is bigger, A or B+C" to investigate the accuracy of pie and bar charts for making part-to-whole comparisons. The later studies show more of an interdisciplinary conversation around data displays, which have become a general tool not limited to statisticians. As a result, the literature becomes fragmented; studies are conducted across different disciplines, with different methods, elicitation questions, protocols, and ultimately, different conclusions.

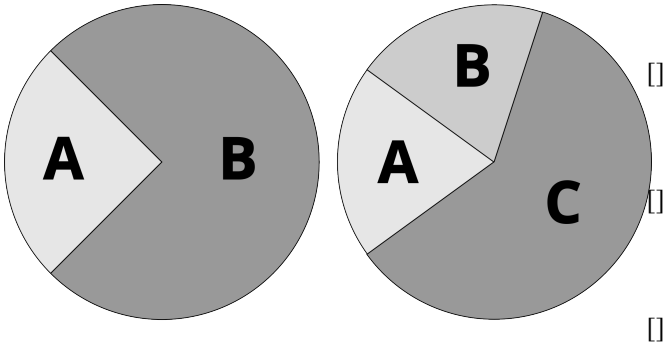

Figure 1: Different elicitation methods used to assess accuracy of pie chart estimates.

Scope and Aims

In this study, we re-examine the historical literature surrounding the use of pie and bar charts, including heuristics as well as empirical studies. We trace guidelines back to experimental studies, where possible, and examine whether justifications based on experimental studies are in fact directly supported by those studies. We begin with an initial set of four JASA papers from the late 1920s and early 1930s: Eells (1926), Croxton and Stryker (1927), von Huhn (1927), and Croxton and Stein (1932). We trace these studies forward in time, examining papers which cite these studies, summaries of the original studies, and any additional information provided relevant to pie and bar charts. In addition, we specifically assess the different designs used in each experimental study, examining how the type of elicitation method impacts the results, as shown in Figure 1. Synthesizing these results, we use the fundamental question of "which is better, pies or bars?" to examine the history of experimental graphics and graphical design guidelines.]{.svp}

References

Brinton, Willard Cope. 1914. *Graphic Methods for Presenting Facts*. New York, The Engineering Magazine Company. http://archive.org/details/graphicmethodsfo00brinrich.

Cleveland, William S., and Robert McGill. 1984. "Graphical Perception: Theory, Experimentation, and Application to the Development of Graphical Methods." *Journal of the American Statistical Association* 79 (387): 531–54. https://doi.org/10.1080/01621459.1984.10478080.

Croxton, Frederick E., and Harold Stein. 1932. "Graphic Comparisons by Bars, Squares, Circles, and Cubes." *Journal of the American Statistical Association* 27 (177): 54–60.

Croxton, Frederick E., and Roy E. Stryker. 1927. "Bar Charts Versus Circle Diagrams." *Journal of the American Statistical Association* 22 (160): 473–82. https://doi.org/10.2307/2276829.

Eells, Walter Crosby. 1926. "The Relative Merits of Circles and Bars for Representing Component Parts." *Journal of the American Statistical Association* 21 (154): 119–32. https://doi.org/10.2307/2277140.

Karsten, K. G. 1923. *Charts and Graphs: An Introduction to Graphic Methods in the Control and Analysis of Statistics*. Prentice-Hall, Incorporated. https://books.google.com/books?id=DNc1AAAAIAAJ.

Secrist, Horace. 1925. *An Introduction to Statistical Methods: A Textbook for College Students, a Manual for Statisticians and Business Executives*. Macmillan. https://www.google.com/books/edition/An_Introduction_to_Statistical_Methods/cuUBAAAAMAAJ?hl=en.

Spence, I., and S. Lewandowsky. 1991. "Displaying Proportions and Percentages." *Applied Cognitive Psychology* 5 (1): 61–77. https://doi.org/10.1002/acp.2350050106.

Vanderplas, Susan, Dianne Cook, and Heike Hofmann. 2020. "Testing Statistical Charts: What Makes a Good Graph?" *Annual Review of Statistics and Its Application* 7 (1): 61–88. https://doi.org/10.1146/annurev-statistics-031219-041252.

VanderPlas, Susan, Goluch C Ryan, and Heike Hofmann. 2019. "Framed! Reproducing and Revisiting 150-Year-Old Charts." *Journal of Computational and Graphical Statistics* 28 (3): 620–34. https://doi.org/10.1080/10618600.2018.1562937.

von Huhn, R. 1927. "Further Studies in the Graphic Use of Circles and Bars: A Discussion of the Eell's Experiment." *Journal of the American Statistical Association* 22 (157): 31–39. https://doi.org/10.2307/2277346.

Wickham, Hadley. 2013. "Graphical Criticism: Some Historical Notes." *Journal of Computational and Graphical Statistics* 22 (1): 38–44. https://doi.org/10.1080/10618600.2012.761140.