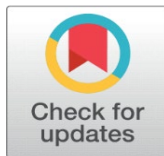


GRAPHICAL AND STATISTICAL REPRESENTATION IN MATHEMATICS: ORIGINS AND RELEVANCE

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ABSTRACT

The pie chart has a history dating back over two centuries. It initially appeared as part of The Statistical Breviary, which featured comprehensive graphical displays detailing the areas, populations, and revenues of European states. William Playfair, known for his earlier creation of the bar chart and his advocacy for using line graphs to illustrate time series data in statistics, also introduced the pie chart as his final major graphical innovation. Playfair was skilled at adapting and refining existing concepts, but the origins and intellectual motivations behind the pie chart and its precursor, the circle chart, are still unclear. While we have a good understanding of the sources that inspired Playfair's bar chart and line graph, the genesis of the pie chart remains a mystery.

Keywords: Pie Chart, Mathematics, Circle, Geometry, Graphics, Bar Diagram, Statistics, Linear Graph

1. INTRODUCTION

In The Statistical Breviary, Playfair aimed to present statistical data for European countries at the turn of the 19th century in graphical form, believing that visually appealing representations were the most effective way to convey distinct ideas about proportion and magnitude. The first chart in the volume depicted pre-French Revolution (1789) European countries, while the second chart illustrated changes by 1801. Countries were represented by circles of varying sizes corresponding to their land areas, with Russia, the largest, depicted by the largest circle, and smaller states like Portugal represented by much smaller circles. Each circle included numerical values of land area inscribed below its diameter. In addition to land masses, populations, and revenues, the charts indicated maritime powers with green shading and nonmaritime powers with red. Populations were represented by vertical red lines to the left of each circle, and tax revenues by vertical yellow lines to the right. Dotted lines connecting the tops of these lines provided a rough indication of the tax burden, though Playfair suggested interpreting their slope rather than their exact angle due to their dependence on circle diameter.

Playfair meticulously added color by hand to each copy of the book after the original copperplate impressions were made, and he likely engraved the plates himself. To depict political subdivisions, Playfair employed various methods. For instance, he distinguished European and Asiatic Dominions within the Russian Empire using concentric circles, with inner circles for European and surrounding annuli for Asiatic dominions. The Turkish Empire's land areas were divided

into three sectors within a single circle, each colored differently (green for Asiatic, red for European, yellow for African), though Playfair did not explain his choice of colors. The second chart, reflecting the 1801 geopolitical landscape after the Luneville peace treaty, illustrated fewer states.

Playfair used a pie chart to show the German Empire's division between Austria and Prussia, and a Venn diagram to represent joint ownership among them. This diagram featured overlapping circles with distinct colors (red for Austrian, yellow for Prussian, green for German princes' territories), highlighting intersections to denote shared territories. Through these charts, Playfair introduced three innovative forms of statistical graph: the circle diagram, the pie chart, and the Venn-like diagram, all designed to facilitate comparison and enhance data memorability. Despite some inaccuracies, Playfair's basic designs remain influential and enduring in the field of statistical visualization to this day.

2. INSPIRATIONS FOR STATISTICAL REPRESENTATION

Playfair's other graphical innovations, such as the bar chart and the application of the line graph to statistics, have clear intellectual origins. The bar chart was influenced by chronological diagrams, which Playfair frequently encountered depicting life spans with solid black bars aligned along a time scale. He was also connected, albeit distantly, to a principal user of this format. For the line graph, Playfair credited his older brother John, who encouraged him to maintain daily temperature records and graph them in the style of contemporary natural philosophers. In contrast, the origins of the pie chart remain obscure in Playfair's works, which extensively detail the development of the bar chart and line graph. This discrepancy raises questions about Playfair's perception of the pie chart's significance; did he not regard its design as important? Today, one might consider the pie chart so intuitive that its invention could have been inevitable. However, before Playfair, no one had published charts utilizing lines, bars, circles, and pies to present statistical data.

John Playfair, a distinguished mathematician, influenced William significantly during their upbringing in Liff, near Dundee, where mathematical discussions were commonplace. John's knowledge encompassed the works of renowned figures like Euler, Leibniz, and medieval philosophers such as Ramón Llull and Giordano Bruno. Llull pioneered circular diagrams to explore logical propositions, while Bruno expanded on Llull's ideas with more complex diagrams. Leibniz later integrated these concepts into his work on combinatorial logic, which influenced Euler's popularization of circle diagrams in 1768. John Playfair's familiarity with Leibniz and Euler's contributions suggests that he imparted this knowledge to William, possibly influencing the latter's use of circles and intersecting circles in his own graphical representations. In summary, while the origins of Playfair's bar chart and line graph are well-documented, the inspiration behind his pie chart remains enigmatic. John Playfair's profound understanding of mathematical history likely shaped William's adoption of circle diagrams, underscoring their intellectual lineage from earlier mathematicians and philosophers.

3. PIE CHARTS AND CIRCLES

Playfair's contributions, particularly his pie charts, did not gain traction in Great Britain, largely due to his controversial personal history. He had a checkered past involving failed and sometimes fraudulent business ventures in London and Paris from the early 1780s onwards. Playfair accumulated significant debts in London and faced accusations of appropriating others' ideas in patents. His involvement in financial scandals in revolutionary Paris further tarnished his reputation, and he narrowly avoided arrest in a dispute with the Bank of England upon returning to London. Despite escaping prosecution in major cases, he was later convicted on minor charges at the Court of Kings Bench. Additionally, Playfair was known for publicly criticizing public figures, actions that invited official disapproval. In contrast to his esteemed brother John, a respected professor and minister in Scotland, William Playfair's unconventional behavior and questionable reputation hindered the acceptance of his charts, especially in academic circles where reputation carried considerable weight during the late 18th and early 19th centuries.

Consequently, his work received scant attention in Great Britain, while it found somewhat more recognition in Germany, where Alexander von Humboldt, John's close friend, embraced Playfair's diagrams. In France, Playfair's publications in Paris attracted notable interest, although not all responses were positive. By the mid-19th century, figures like Charles-Joseph Minard began using pie charts in their statistical maps, marking a significant shift in their adoption. In the United Kingdom, the acceptance of statistical graphs was delayed until figures like William Stanley Jevons, influenced by Playfair, began employing them in the 1860s. Jevons, in turn, played a crucial role in establishing graphics within British statistical circles, laying the groundwork for later advancements by statisticians like Karl Pearson.

However, the pie chart faced criticism, with early commentators like Brinton questioning its effectiveness, leading to psychological experiments on graph perception.

These studies often showed mixed results, with varying quality and inconclusive findings regarding the pie chart's superiority over other graphical forms. Recent research indicates that for simple tasks such as estimating single proportions or comparing a small number of proportions, the pie chart performs as well as, if not better than, other commonly used charts. Its ability to provide an integrated representation of the whole and offer multiple natural anchors (0%, 25%, 50%, 75%, 100%) for accurate estimation sets it apart from competitors like the bar chart, which may lack such references without a dedicated scale. Thus, while historical prejudices against the pie persist, particularly regarding the accuracy of proportion estimation, empirical evidence suggests its viability in appropriate contexts.

4. CONCLUDING WITH ITS CONTEMPORARY USE

Pie charts are significantly less prevalent compared to bar charts or line graphs across various types of publications. They are particularly infrequent in business and scientific literature. In popular news magazines, approximately one out of every ten graphs features a pie chart. Bar and line graphs appear about twice as often as pie charts, with line graphs being the most widely used type overall, constituting more than half of all charts in some publications. Overall, Playfair's graphical innovations represent approximately half of all diagrams in news magazines and between 60% to 80% in the business and scientific press. Despite its relatively modest usage compared to other graph types, the pie chart has garnered a substantial following due to its ability to visually represent a small number of proportions in an attractive manner. Enduring for over two centuries, the pie chart remains a resilient and effective tool for displaying data and shows no indication of losing its utility or appeal.

CONFLICT OF INTERESTS

None.

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