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DISCUSSION AND COMMENTS

Approche graphique en analyse des données

The invention and use of statistical charts

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Why were statistical graphs not introduced before the end of the XVIIIth century and why were they not widely used before the end of the XIXth century? Historians of statistics have searched assiduously for graphs before the time of PLAYFAIR but have found only a handful of isolated and often peculiar examples (see BIDERMAN, 1990; HANKINS, 1999; WAINER & VELLEMAN, 2001). These oddities did not influence subsequent developments, and recognizably modern forms did not appear until the *Commercial and Political Atlas* of 1786. In this remarkable volume, PLAYFAIR introduced 44 examples of the statistical time series chart and a solitary bar chart. In the *Statistical Breviary* of 1801, he added the circle diagram and pie chart to the list of his graphical inventions. How was PLAYFAIR able to invent new and fundamental forms of data display that are essentially the same as those in use today; how was he able to do so without precursors; and why was he so confident that he had found ways of presenting data that would have enduring value? Unlike earlier idiosyncratic examples, PLAYFAIR did not make isolated use of his inventions : over a period of 36 years more than one hundred exemplars of his statistical charts appeared in a variety of publications, some in multiple editions. VALOIS suggests some reasons why PLAYFAIR was able to do what nobody had done before and I would like to explore these ideas further.

The organized collection of extensive statistical data originated in 1622 with John of GRAUNT and his *Observations on the London Bills of Mortality.* Shortly thereafter, we see the appearance of several political and economic tracts containing tables of figures comparing revenues from successive years. Thus, more than a century before PLAYFAIR, the raw materials necessary for the invention of statistical graphs were present but no one else had the inspiration to represent numerical data as pictures. VALOIS is almost certainly correct when he asserts that a mistrust of sense perception on the part of DESCARTES and other philosophers was a powerful impediment to the development of empirical methods of investigation. BIDERMAN (1990)

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has made a similar suggestion and the mathematician BOCHNER (1981) has expressed surprise that, although " hardly anything ... is more commonplace and utilitarian than a 'pictorial' graph or chart ", mathematics was slow to embrace the idea. BOCHNER also attributed the lack of acceptance to DESCARTES' philosophical motivations. It seems ironic to think that DESCARTES might have rejected data graphs using Cartesian coordinates.

Generally, in the XVIIth century, illustration in scientific writing was regarded with deep suspicion and even eminent experimenters such as Robert HOOKE felt compelled to sound a note of caution stating, in his *Micrographia* of 1665, that " Pictures of things which only serve for ornament or Pleasure, or the Explication of such things as can better be describ'd by words is rather noxious than useful, and serves to divert and disturb the Mind, and sways it with a kind of Partiality or Respect. " HOOKE was very sensitive to the possibility of distortion or misrepresentation in his illustrations and took frequent pains to assure the reader of accuracy, or to point out defects in the representation. However, by the XVIIIth century, the philosophical tide had turned towards empiricism and the practice of including illustrations in published scientific work became more common. Of course, the PLAYFAIR brothers were thoroughly familiar with the writings of the leading empiricist thinkers of the Scottish Enlightenment : the ideas of HUME, REID, and STEWART were similar to their own. John PLAYFAIR was a particularly close friend and colleague of Dugald STEWART, who had studied under Thomas REID, author of the "common sense" philosophy, a system that rejected many of the ideas of DESCARTES and MALEBRANCHE.

Nonetheless, despite the shift to empiricism in philosophy and science, a general mistrust of pictorial representation lingered, with XVIIIth and early XIXth century academics reluctant to publish graphs of either physical or statistical data, probably because of concerns regarding accuracy. Even James WATT, who shared PLAYFAIR's enthusiasm for pictorial representation and made graphical inventions of his own, recommended the addition of tables to the first edition of the *Atlas*. WATT advised PLAYFAIR : "it might be proper to give in letter press the Tables from which the Charts have been constructed ... for the charts now seem to rest on your own authority, and it will naturally be enquired from whence you have derived your intelligence." PLAYFAIR, who must have worried about acceptance, took WATT's advice and the *Atlas* of 1786 included tables.

Another barrier was the process of printing the charts. ESPINASSE (1962) has argued that in the XVIIth century, men of science like HOOKE were more versatile, used to interacting with merchants, tradesmen, and craftsmen, whereas by the XVIIIth century the scientist had become more studious, aloof, and less likely to possess practical and mechanical expertise. However, PLAYFAIR did have the required skills; his early training was singularly appropriate for an inventor of charts. His education in mathematics was at the hands of his older brother John, one of Scotland's foremost mathematicians and natural philosophers. John's scientific approach was highly empirical and he gave his younger brother the daily task of keeping a graphical record of

temperature, acknowledged by William as the inspiration for his economic time series chart. Then, at the age of fourteen, William was apprenticed to the eminent Scottish engineer Andrew MEIKLE and, three years later, he moved to Boulton & Watt in Birmingham to work under the greatest Scottish engineer of all time. William served as James WATT's personal draughtsman, preparing and copying drawings of the steam engines. During his time in Birmingham, PLAYFAIR also encountered Joseph PRIESTLEY, whose chronological diagrams inspired the bar chart.

Early printed illustrations were reproduced using woodcuts. Because both the woodcut and the pieces of type were in relief, the blocks for illustration and the type could be locked into the same form allowing both text and picture to appear on the same page. However, carving woodcut reliefs was a time-consuming and expensive task reserved to skilled artisans. Consequently, from the XVIth to the XVIIIth century, illustrations were usually made using an engraved copper plate that was inked and wiped so that ink remained only in the incisions, before being transferred to paper under pressure. Mastering this process was easy for PLAYFAIR, the engineer, and, in order to save printing costs, he frequently engraved the lines on the copper plates himself, leaving the more delicate work of lettering to the printer. However, since this *intaglio* method was not compatible with printing in relief, the illustrations had to be printed separately from the pages of text. This is the reason why almost all of PLAYFAIR's charts are printed on flyouts from the main text.

But PLAYFAIR's charts were not readily accepted (FUNKHOUSER, 1937), especially in Britain where concerns regarding accuracy were not eased by his occasional carelessness and his less than reputable personal standing (SPENCE & WAINER, 1997). He was received more kindly in Germany and France, gaining a measure of approval from the professional geographer Alexander von Humboldt to the amateur Louis XVI, in whose opinion the charts " spoke all languages and were very clear and easily understood " (PLAYFAIR, 1822-23). Nevertheless, there was still considerable opposition among statisticians and there was no general adoption of the new graphical methods until the second half of the XIXth century when MINARD and BERTILLON incorporated some of PLAYFAIR's devices in their cartographical work (PALSKY, 1996).

Eventually statistical charts also started to catch on in Britain, more than 50 years after their conception there. W.S. JEVONS, a key figure in the early development of quantitative methods in economics, was an enthusiastic proponent of graphs, using them in his own work and bringing the name of PLAYFAIR to a new generation of academics, among them EDGEWORTH, PEARSON and KEYNES. It is important to note, however, that JEVONS had a great deal of difficulty in getting his graphs published, almost a century after PLAYFAIR. For example, he was not successful in publishing his atlas of historical statistics, which contained many graphs in the style of PLAYFAIR. John Maynard KEYNES has noted that JEVONS "would spend hours arranging his charts, plotting them, sifting them, tinting them neatly with delicate pale colors like the slides of the anatomist, and all the time poring

over them and brooding over them to discover their secret. It is remarkable how few imitators he had in the black arts of inductive economics in the fifty years after 1862. But today he can certainly claim an unnumbered progeny." Yet, despite JEVONS's enthusiastic rediscovery and the later advocacy of KEYNES, EDGEWORTH and PEARSON, the role of PLAYFAIR in the invention of statistical graphs remained little known until the second half of the XXth century.

VALOIS notes that cognitive science has played an important role in the study of statistical graphs during the last two decades. This interest in psychological aspects is not completely new ; PLAYFAIR was acutely aware of the importance of perceptual and cognitive processes. For example, he wanted to find a better way of presenting tabular data and, as he said in the Atlas, " a man who has carefully investigated a printed table, finds, when done, that he has only a very faint and partial idea of what he has read ". Later, in the *Statistical Breviary*, PLAYFAIR claimed that " The advantages proposed by [the graphical] mode of representation, are to facilitate the attainment of information, and aid the memory in retaining it ... Of all the senses, the eye gives the liveliest and most accurate idea of whatever is susceptible of being represented to it ; and when proportion between different quantities is the object, then the eye has an incalculable superiority ". PLAYFAIR's introduction of the circle and pie diagrams, in the Breviary, was intended to make easier the comparison of land areas of European and Asian nations ; he knew that a comparison of the irregular shapes in a conventional atlas was problematic and that ordering countries by size was a difficult visual task. His solution was to use a common shape and thus exploit the eye's capability of making comparative judgments with high accuracy ; " for where the forms are not similar, the eye cannot compare them easily nor accurately. " Thus PLAYFAIR was able to offer remarkable insights into the psychology of graphs long before more recent authors who have exploited the findings of modern cognitive neuroscience.

PLAYFAIR was at pains to point out that his charts were not merely a new and different method of display. He understood that graphs could form the basis for new ideas or models. For example, after completing a trial graph of some data, he once said that "the first rough draft [gave] me a better comprehension of the subject, than all that I had learnt from occasional reading, for half my lifetime". PLAYFAIR charted data to discover as well as to present ; in that respect, he anticipated the exploratory uses of graphs that were to become popular more than a century later (SPENCE & GARRISON, 1993).

There are many other stimulating ideas worthy of comment in the fine paper by VALOIS. In the tradition of BERTIN, he has given us a new typology, in which he has usefully drawn attention to the under use of two classes of graph based on parallel and radial coordinates. When such neglect is discovered, it is incumbent on the statistician and the cognitive scientist to ask why. It may be that the forms are insufficiently familiar and that, if better known, they have the potential to be more widely used. On the other hand, the graph may

be unfamiliar because readers have rejected it ; the mental operations required may be too taxing. It is unclear which explanation is true in the case of these two graphs. Just as with PLAYFAIR's inventions, the true test will be how well they stand up after one or two centuries of use.

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