

5. Displaying Data and Accessing Results

Bennett, K. B., & Flach, J. M. (1992). Graphical display: Implications for divided attention, focused attention, and problem-solving. *Human Factors*, 34(5), 513-533.

When completing tasks in complex, dynamic domains observers must consider the relationships among many variables (e.g., integrated tasks) as well as the values of individual variables (e.g., focused tasks). A critical issue in display design is whether or not a single display format can achieve the dual design goals of supporting performance at both types of tasks. We consider this issue from a variety of perspectives. One relevant perspective is the basic research on attention and object perception, which concentrates on the interaction between visual features and processing capabilities. The principles of configularity are discussed, with the conclusion that they support the possibility of achieving the dual design goals. These considerations are necessary but not sufficient for effective display design. Graphic displays map information from a domain into visual features; the tasks to be completed are defined in terms of the domain, not in terms of the visual features alone. The implications of this subtle but extremely important difference are discussed. The laboratory research investigating alternative display formats is reviewed. Much like the attention literature, the results do not rule out the possibility that the dual design goals can be achieved. [Authors' abstract]

Best, L. A., Smith, L. D., & Stubbs, D. A. (2001). Graph use in psychology and other sciences. *Behavioural Processes*, 54(3), 155-165.

Since the early 19th century, graphs have been recognised as an effective method of analysing and representing scientific data. However, levels of graph use have varied widely since then, partly due to increasing reliance on inferential statistics in some fields. Recent studies indicate that graph use is closely related to the 'hardness' of scientific disciplines, and that this finding holds for journal articles and textbooks across the subfields of psychology. In the area of animal behaviour, journals devote about one-sixth of their page space to graphs, a level of graph use approximating that of biology and physics. Implications for the training of scientists in the use of visual displays are considered. [Authors' abstract]

Carswell, C. M., Frankenberger, S., & Bernhard, D. (1991). Graphing in depth: Perspectives on the use of three-dimensional graphs to represent lower-dimensional data. *Behaviour and Information Technology*, 10(6), 459-474.

Carswell, C. M., & Ramzy, C. (1997). Graphing small data sets: Should we bother? *Behaviour and Information Technology*, 16(2), 61-71.

While display designers tend to agree that the communication of large amounts of quantitative information calls for the use of graphs, there is less consensus about whether graphs should be used for small, summarized data sets. In the present study, three groups of 16 subjects viewed 11 sets of time series data presented as

tables, bar charts, or line graphs. Data sets varied in size (4, 7, or 13 values) and complexity (number and type of departures from linearity). Subjects provided written interpretations of each of the data sets, and these interpretations were scored for (1) overall number of propositions pertaining to the data set as a whole (global content), (2) number of propositions describing relations within a subset of the data (local content), and (3) number of references to specific data values (numeric content). For the larger (7- and 13-point) data sets, interpretations based on bar charts included the greatest overall global content, but line graph interpretations proved to be most sensitive to the actual information content (complexity) of the data sets. The greater sensitivity of the line graphs was still obtained with four-point data sets; however, this advantage was greater for men than for women. For data sets of all sizes, but especially for the smallest sets, gender differences in interpretation content were obtained. These differences are discussed within the context of more general individual differences presumed to exist in graph-reading strategies. [Authors' abstract]

Cleveland, W. S. (1985). *The elements of graphing data*. Monterey, CA: Wadsworth.

Reviewed by Simon, G. (1987). The elements of graphing data (book). *Journal of the American Statistical Association*, 82(397), 348-349.

Cleveland, W. S. (1993). *Visualizing data*. Summit, NJ: Hobart Press.

Reviewed by Welsh, A. H. (1994). Visualizing data (book). *Journal of the American Statistical Association*, 89(427), 1136-1138.

Cleveland, W. S. (1994). *The elements of graphing data*. Summit, NJ: Hobart Press.

Reviewed by Ziegel, E. R. (1997). Book reviews. *Technometrics*, 39(2), 237-238.

Cleveland, W. S., & McGill, R. (1984). Graphical perception: Theory, experimentation, and application to the development of graphic methods. *Journal of the American Statistical Association*, 79(387), 531-534.

The subject of graphical methods for data analysis and for data presentation needs a scientific foundation. In this article we take a few steps in the direction of establishing such a foundation. Our approach is based on graphical perception—the visual decoding of information encoded on graphs—and it includes both theory and experimentation to test the theory. The theory deals with a small but important piece of the whole process of graphical perception. The first part is an identification of a set of elementary perceptual tasks that are carried out when people extract quantitative information from graphs. The second part is an ordering of the tasks on the basis of how accurately people perform them. Elements of the theory are tested by experimentation in which subjects record their judgments of the quantitative information on graphs. The experiments validate these elements but also suggest that the set of elementary tasks should be

expanded. The theory provides a guideline for graph construction: Graphs should employ elementary tasks as high in the ordering as possible. This principle is applied to a variety of graphs, including bar charts, divided bar charts, pie charts, and statistical maps with shading. The conclusion is that radical surgery on these popular graphs is needed, and as replacements we offer alternative graphical forms-dot charts, dot charts with grouping, and framed-rectangle charts. [Authors' abstract]

Cleveland, W. S., & McGill, R. (1985). Graphical perception and graphical methods for analyzing scientific data. *Science*, *229*, 828-833.

Graphical perception is the visual decoding of the quantitative and qualitative information encoded on graphs. Some recent theoretical/experimental investigations of graphical perception are described, identifying certain elementary graphical-perception tasks that are performed in the visual decoding of quantitative information from graphs. [Authors' abstract]

Dent, B. D. (1999). *Cartography: Thematic map design* (5th ed.). New York, NY: McGraw Hill.

Reviewed by Macdonald, A., & Mackaness, W. A. (2000). Book reviews. *International Journal of Geographical Information Science*, *14*(4), 407-409.

Gillian, D. J., Wickens, C. D., Hollands, J. G., & Carswell, C. M. (1998). Guidelines for presenting quantitative data in HFES publications. *Human Factors*, *40*(1), 28-41.

This article provides guidelines for presenting quantitative data in papers for publication. The article begins with a reader-centered design philosophy that distills the maxim "know thy user" into three components: (a) know your users' tasks, (b) know the operations supported by your displays, and (c) match user's operations to the ones supported by your display. Next, factors affecting the decision to present data in text, tables, or graphs are described: the amount of data, the readers' informational needs, and the value of visualizing the data. The remainder of the article outlines the design decisions required once an author has selected graphs as the data presentation medium. Decisions about the type of graph depend on the readers' experience and informational needs as well as characteristics of the independent (predictor) variables and the dependent (criterion) variable. Finally, specific guidelines for the design of graphs are presented. The guidelines were derived from empirical studies, analyses of graph readers' tasks, and practice-based design guidelines. The guidelines focus on matching the specific sensory, perceptual, and cognitive operations required to read a graph to the operations that the graph supports. [Authors' abstract]

Gilmore, A. & Hattie, J.A. (2001). Understanding usage of an internet based information resource for teachers: The Assessment Resource Banks. *New Zealand Journal of Educational Studies*, *32*(2), 237-258.

Guerard, E. B. (2000, August 7). Web site lets parents compare their kids' test scores with peers'. *eSchool News*. Retrieved March 31, 2009, from <http://www.eschoolnews.com/news/showstory.cfm?ArticleID=1337>

Harris, R. L. (1997). *Information graphics: A comprehensive illustrated reference*. Mumbai, India: Jaico.

Reviewed by Wilson, R. D. (1998). Information graphics: A comprehensive illustrated reference. *Journal of the American Society for Information Science*, 49(4), 383-384.

Jacoby, W. G. (1997). *Statistical graphics for univariate and bivariate data*. Thousand Oaks, CA: Sage Publications. (Monograph #117)

The purpose of this monograph is to present the major techniques that fall under the general heading of statistical graphics used in the social sciences field. The primary focus of the discussion is on analytic graphics. In other words, I concentrate on graphical techniques that the researcher would employ as an integral part of the data analysis process. There is little explicit coverage of so-called presentational graphics or the kinds of displays that are intended primarily for communicating completed analyses to a lay audience. [Author's abstract]

Jacoby, W. G. (1998). *Statistical graphics for visualizing multivariate data*. Thousand Oaks, CA: Sage Publications. (Monograph #120)

This monograph will examine graphical displays that are useful for visualizing multivariate data. As such, it will pick up the discussion that was begun in the companion volume within this series, *Statistical Graphics for Visualizing Univariate and Bivariate Data* (W. G. Jacoby, 1997). The basic objective here is to obtain pictorial representations of quantitative information. Multivariate data pose special challenges for statistical graphics, beyond those encountered with univariate or bivariate data. The central problem is to represent information that can vary along several dimensions (typically, one for each variable) in a display medium that is almost always inherently 2-dimensional in nature--a printed page or computer display. [Author's abstract]

Knupp, T., & Ansley, T. (2008, March). *Online, state-specific assessment score reports and interpretive guides*. Paper presented at the meeting of the National Council on Measurement in Education, New York, NY.

The study was to (a) identify states with score reports and interpretive guides available via the Internet, (b) identify the characteristics of online test score information that meet score reporting standards as specified by government requirements and measurement experts, and (c) describe the utility of the online assessment score information. It is found that states reported their scores online

in a variety of ways; different score information was available, different file types were available for download, different grades had scores available, and the data were disaggregated relative to different groups of students. The interpretive guides were equally as variable. The materials most commonly found in interpretive guides included listing additional resources, giving the meaning of the scores, and stating the purpose of the assessment. Information about test score precision and common misinterpretations of test scores were least likely to be mentioned in the guides. [Authors' abstract]

Kosslyn, S. (1985). Graphics and human information processing. *Journal of the American Statistical Association*, 80(391), 499-512.

Kosslyn, S. (1994). *Elements of graph design*. New York, NY: W. H. Freeman.

Reviewed by Schreiner, D. E., & Murphy, A. J. (1996). Book reviews. *Technical Communication*, 43(3), 286-289.

Krug, S. (2000). *Don't make me think! A common sense approach to web usability*. Indianapolis, IN: QUE.

Meagher-Lundberg, P. (2000). *Comparison variables useful to teachers in analysing assessment results* (Tech. Rep. No. 1). Auckland, NZ: University of Auckland, Project asTTle.

Meagher-Lundberg, P. (2001). *Output reporting design: Focus group 2* (Tech. Rep. No. 10). Auckland, New Zealand: University of Auckland.

Miller, G. A. (1956). The magical number seven, plus or minus two: Some limits on our capacity for processing information. *Psychological Review*, 63(2), 81-97.

A variety of researches are examined from the standpoint of information theory. It is shown that the unaided observer is severely limited in terms of the amount of information he can receive, process, and remember. However, it is shown that by the use of various techniques, e.g., use of several stimulus dimensions, recoding, and various mnemonic devices, this informational bottleneck can be broken. [Author's abstract]

Milroy, R., & Poulton, E. C. (1978). Labeling graphs for increased reading speed. *Ergonomics*, 21(1), 55-61.

Three methods of labeling graphs were compared:

1. direct labeling on the functions
2. a key inserted on the graph field below the functions
3. a key inserted below the figure in the position of the figure caption.

In both a separate-groups comparison and in a subsequent within-subjects comparison, direct labeling gave reliably the quickest readings ($p < 0.01$) without

loss of accuracy. Reading the labels directly appeared to involve fewer steps and depend less upon short-term memory. [Authors' abstract]

Monmonier, M. (1991). *How to lie with maps*. Chicago, IL: University of Chicago Press.

Reviewed by Morrison, P. (1991). Necessary white lies. *Scientific American*, 265(1), 124-125.

Nielsen, J. (1993). *Usability engineering*. San Diego, CA: Morgan Kaufmann.

Reviewed by Albers, M. J., & Lisberg, B. C. (2000). Information design: A bibliography. *Technical Communication*, 47(2), 170

Nielsen, J. (2000). *Design web usability: The practice of simplicity*. Indianapolis, IN: New Riders Publishing.

Norman, D. A. (2002). *The design of everyday things*. New York, NY: Basic Books.

Originally published as *The psychology of everyday things* in 1988 and reviewed by Watts, P. (1989). The psychology of everyday things (book review). *Management Review*, 78(5), 60-61.

Also reviewed by Schmeil, A. (2008). The design of everyday things (book review). *Studies in Communication Sciences*, 8(2), 408-410.

Norman, D. A. (2004). *Emotional design: Why we love (or hate) everyday things*. New York, NY: Basic Books.

Reviewed by Gold, S. F., Chenoweth, E., & Zaleski, J. (2003). Emotional Design: Why we love to hate everyday things (book). *Publishers Weekly*, 250(45), 50-51.

Pickle, L. W., & Herrmann, D. (1994). The process of reading statistical maps: The effect of color. *Statistical Computing and Statistical Graphics Newsletter*, 5(1), 12-16.

Rubin, J. (1994). *Handbook of usability testing*. New York, NY: John Wiley & Sons.

Reviewed by Shaw, D. (1996). Handbook of usability testing: How to plan, design, and conduct effective tests. *Journal of the American Society for Information Science*, 47(3), 258-259.

Salvagno, M., & Teglassi, H. (1987). Teacher perceptions of different types of information in psychological reports. *Journal of School Psychology*, 25(4), 415-424.

One hundred and sixty elementary school teachers rated the helpfulness of various types of information on test-based and observation-based reports. There was no difference between the test-based and the observation-based reports in overall

rating of helpfulness. On both types of reports, interpretive material was consistently rated as more helpful than factual or descriptive information in all content areas. On the test-based report, information about personality dynamics was rated as more helpful than description of intellectual functioning or academic achievement. Teachers desire interpretations that go beyond that which is immediately observable in the behavior or test data. They prefer recommendations that provide specific guidelines for implementation and are easy to carry out. The type of report as well as the gender of the child described in the report influenced teachers' responses to recommendations. [Authors' abstract]

Simkin, D., & Hastie, R. (1987). An information processing analysis of graph perception. *Journal of the American Statistical Association*, 82(398), 454-465.

Recent work on graph perception has focused on the nature of the processes that operate when people decode the information represented in graphs. We began our investigations by gathering evidence that people have generic expectations about what types of information will be the major messages in various types of graphs. These graph schemata suggested how graph type and judgment type would interact to determine the speed and accuracy of quantitative information extraction. These predictions were confirmed by the finding that a comparison judgment was most accurate when the judgment required assessing position along a common scale (simple bar chart), had intermediate accuracy on length judgments (divided bar chart), and was least accurate when assessing angles (pie chart). In contrast, when the judgment was an estimate of the proportion of the whole, angle assessments (pie chart) were as accurate as position (simple bar chart) and more accurate than length (divided bar chart). Proposals for elementary information processes involving anchoring, scanning, projection, superimposition, and detection operators were made to explain this interaction. [Authors' abstract]

Tufte, E. R. (1983). *The visual display of quantitative information*. Cheshire, CT: Graphics Press.

The classic book on statistical graphics, charts, tables. Theory and practice in the design of data graphics, 250 illustrations of the best (and a few of the worst) statistical graphics, with detailed analysis of how to display data for precise, effective, quick analysis, design of the high-resolution displays, small multiples, editing and improving graphics, the data-ink ratio. Time-series, relational graphics, data maps, multivariate designs. Detection of graphical deception: design variation vs. data variation, sources of deceptions, esthetics and data graphical displays. [Copied March 31, 2009, from http://www.edwardtufte.com/tufte/books_vdqi]

Reviewed by Fienberg, S. E. (1985). The visual display of quantitative information (book review). *Journal of Economic Literature*, 23(4), 1798.

Tufte, E. R. (1990). *Envisioning information*. Cheshire, CT: Graphics Press.

This book celebrates escapes from the flatlands of both paper and computer screen, showing superb displays of high-dimensional complex data. The most design-oriented of Edward Tufte's books, *Envisioning Information* shows maps, charts, scientific presentations, diagrams, computer interfaces, statistical graphics and tables, stereo photographs, guidebooks, courtroom exhibits, timetables, use of color, a pop-up, and many other wonderful displays of information. The book provides practical advice about how to explain complex material by visual means, with extraordinary examples to illustrate the fundamental principles of information displays. Topics include escaping flatland, color and information, micro/macro designs, layering and separation, small multiples, and narratives. [Copied March 31, 2009, from http://www.edwardtufte.com/tufte/books_ei]

Reviewed by Morrison, P. (1990). *Envisioning information* (book). *Scientific American*, 263(4), 131.

Tukey, J. W. (1990). Data-based graphics: Visual display in the decades to come. *Statistical Science*, 5(3), 327-339. Retrieved March 31, 2009, from <http://www.jstor.org/stable/2245820>

Tversky, B., & Schiano, D. J. (1989). Perceptual and conceptual factors in distortions in memory for graphs and maps. *Journal of Experimental Psychology: General*, 118(4), 387-398.

We propose that representations of visual stimuli are a consequence of both perceptual and conceptual factors that may be revealed in systematic errors in memory. Three experiments demonstrated increased (horizontal or vertical) symmetry in perception and memory of nearly symmetric curves in graphs and rivers in maps. Next, a conceptual factor, an accompanying description biasing toward symmetry or asymmetry, also distorted memory in the expected direction for the symmetric descriptions. In the two final experiments, we investigated conceptual factors in selection of a frame of reference. Subjects remembered lines in graphs, but not in maps, as closer to the imaginary 45° line. Combined with earlier research, this suggests that the reference frame for map lines is the canonical axes and for graph lines, the imaginary 45° line. [Authors' abstract]

U.S. Department of Health & Human Services. (2009). *Usability guide*. Retrieved March 31, 2009, from <http://usability.gov/>

Vernon, M. D. (1952). The use and value of graphical methods of presenting quantitative data. *Occupational Psychology*, 26, 22-24.

Wainer, H. (1984). How to display data badly. *The American Statistician*, 38(1), 137-147.

The aim of good data graphics is to display data accurately and clearly. This definition is used as a point of departure for developing 12 rules of bad data

display: (1) show as little data as possible (minimize the data density); (2) hide what data you do show (minimize the data-ink ratio); (3) ignore the visual metaphor altogether; (4) only order matters (The Pravda School of Ordinal Graphics); (5) graph data out of context; (6) change scales in mid-axis; (7) emphasize the trivial (ignore the important); (8) jiggle the baseline; (9) order graphs and tables alphabetically; (10) label illegibly, incompletely, incorrectly, and ambiguously; (11) more is murkier (more decimal places and more dimensions); and (12) if it has been done well in the past, think of a new way to do it. Although the tone of this presentation is light, and points in the wrong direction, the aim is serious. The 12 "rules" point clearly toward an outlook that provides many hints for good display. [Author's abstract]

Wainer, H. (1990). Graphical visions from William Playfair to John Tukey. *Statistical Science*, 5(3), 340-346.

This paper discusses the similarities and differences in Playfair and Tukey's visions of what graphically displaying quantitative phenomena can do now, and might do in the future. As part of this discussion we examine: (1) how fundamental graphic tools have become to the scientist, (2) three instances where modern views of graphics are unchanged since Playfair's time, and (3) one area where there has been a change. The paper concludes with a discussion of five important areas of current and future graphic concern. [Author's abstract]

Wainer, H. (1990). Measuring graphicacy. *Chance*, 3(4), 52-58.

Wainer, H. (1991). Integrating figures and text. *Chance*, 4(3), 58-60.

Wainer, H. (1991). Elegance, grace, impact and graphical displays. *Chance*, 4(4), 45-47.

Wainer, H. (1992). Understanding graphs and tables. *Educational Researcher*, 21(1), 14-23.

Quantitative phenomena can be displayed effectively in a variety of ways, but to do so, requires an understanding of both the structure of the phenomena and the limitations of candidate display formats. This article (a) recounts three historic instances of the vital role data displays played in important discoveries, (b) provides three levels of information that form the basis of a theory of display to help us better measure both display quality and human graphicacy, and (c) describes three steps to improve the quality of tabular presentation. [Author's abstract]

Wainer, H. (1993). Making readable overhead displays. *Chance*, 6(2), 46-49.

Wainer, H. (1993). Graphing multiple comparisons: Some comments on Tukey. *Journal of Computational and Graphical Statistics*, 2(1), 35-40.

Wainer, H. (1993). Graphical answers to scientific questions. *Chance*, 6(4), 48-50.

Wainer, H. (1996). Depicting error. *The American Statistician*, 50(2), 101-111.

Discusses the importance of minimizing errors in the presentation of data to prevent misinterpretation and incorrect inferences. Alternatives for the effective communication of errors; Tabular and graphical display of errors; Focus of the study on errors in means. [Author's abstract]

Wainer, H. (1996). Using trilinear plots for NAEP data. *Journal of Educational Measurement*, 33(1), 41-55.

Understanding the distribution of achievement levels of students' performance in the National Assessment of Educational Progress (NAEP) is aided through the use of the trilinear chart. In this article, this chart is described and its use illustrated with data from the 1992 state NAEP mathematics assessment. It is shown that one can see readily the trends in performance for different demographic groups for all of the 44 participating jurisdictions simultaneously. It is suggested that this graphical form may be useful in other contexts, as well. [Author's abstract]

Wainer, H. (1997). Improving tabular displays with NAEP tables as examples and inspirations. *Journal of Educational and Behavioral Statistics*, 22(1), 1-30.

The modern world is rich with data; an inability to effectively utilize these data is a real handicap. One common mode of data communication is the printed data table. In this article we provide four guidelines the use of which can make tables more effective and evocative data displays. We use the National Assessment of Educational Progress both to provide inspiration for the development of these guidelines and to illustrate their operation. We also discuss a theoretical structure to aid in the development of test items to tap students' proficiency in extracting information from tables. [Author's abstract]

Wainer, H. (1997). *Visual revelations: Graphical tales of fate and deception from Napoleon Bonaparte to Ross Perot*. New York, NY: Copernicus.

Reviewed by Ree, M. J., & Summers, L. (1998). Visual revelations: Graphic tales of fate and deception from napoleon bonaparte to ross perot. *Personnel Psychology*, 51(1), 226-229.

Wainer, H. (1997). Some multivariate displays in NAEP. *Psychological Methods*, 2(1), 34-63.

The principal goal of graphic display is to ease access to complex information. Simple univariate displays are easy to understand but usually do not have the capability to transmit accurately the often complex structure of multivariate data. Multivariate displays were specifically designed for exactly this purpose. The

National Assessment of Educational Progress (NAEP) generates data of a multivariate richness and complexity that defies accurate univariate transmission. The broad use and understanding of the information NAEP provides can be aided through the use of more suitable and evocative data displays. In this article, we demonstrate the limitations of univariate displays and suggest some multivariate displays that may enable us to understand, and thence communicate, what is contained in NAEP more fully. [Author's abstract]

Wainer, H. (2002). Clear thinking made visible: Redesigning score reports for students. *Visual Revelations*, 15(1), 56-58.

Wainer, H. (2009). *Picturing the uncertain world: How to understand, communicate, and control uncertainty through graphical display*. Princeton, NJ: Princeton University Press.

Wainer, H., Hambleton, R. K., & Meara, K. (1999). Alternative displays for communicating NAEP results: A redesign and validity study. *Journal of Educational Measurement*, 36(4), 301-335.

Presents a redesign and validity study of displays for communicating National Assessment of Educational Progress (NAEP) results in the United States. Use of the methodology to aid the evolution of data displays; Drawbacks of using the NAEP reports; Comparison between the accuracy of the original and redesigned formats. [Authors' abstract]

Wainer, H., & Thissen, D. (1981). Graphical data analysis. *Annual Review of Psychology*, 32, 191-241.

Focuses on the development of graphical methods for data analysis and communication. History of the use of visual displays to present quantitative materials; Characteristics of a graphical display; Usability of graphical displays. [Authors' abstract]

Zenisky, A. L., Hambleton, R. K., & Sireci, S. G. (2009, April). *At or above proficient: The reporting of NAEP results in the internet age*. Paper presented at the meeting of the National Council on Measurement in Education, San Diego, CA.

The purpose of this paper is to provide a brief overview of the web-based score reporting practices used by the National Assessment of Educational Progress (NAEP), as an example of the Internet as a score reporting (and test information) medium. For states and other groups involved in reporting the results of large-scale educational tests, NAEP's reporting efforts serve as an example of the kinds of materials that testing programs can make available, and the ways in which test data and information can be shared in an online setting. Stakeholders interested in NAEP data can get access to a wide range of information, and in the following sections, we provide an overview of the information included in NAEP's web

presence with respect to both content and format. These topic areas discussed are 1) the NAEP homepage, 2) interactive/media tools, 3) static, data-oriented web pages, and 4) programmatic/informational web pages. For each grouping, we offer some take-home suggestions for testing agencies tasked with developing and maintaining online assessment resources for large-scale tests. [Authors' introduction]