3-1-2009

Information Extraction From Different Data Representation Forms: Charts and Tables

Karthikeyan Umapathy
k.umapathy@unf.edu

Janice M. Engberg

Layne F. Wallas

Follow this and additional works at: http://aisel.aisnet.org/sais2009

INFORMATION EXTRACTION FROM DIFFERENT DATA REPRESENTATION FORMS: CHARTS AND TABLES

Janice M. Engberg
University of North Florida

Karthikeyan Umapathy
University of North Florida
k.umapathy@unf.edu

F. Layne Wallace
University of North Florida
lwallace@unf.edu

ABSTRACT

Presenting data in the form of graphs and tables has long been considered as an important tool for decision making. Extracting information from these presentation forms are considered to be cognitively intensive tasks. Prior research works on aspects of presentation forms have produced inconsistent and conflicting results. In this study, we examine effects of tabular and graphical (bar, line, and pie) forms on information extraction. Graphs were examined with solid and textured patterns as well. We conducted a laboratory experiment where in subjects answered set of questions which would require them to extract information from the presentation display. Our study reveals that tables, even though they have higher response rate, produced more accurate results than graphs. Comparison within graphs showed that bar charts had a lower response rate than pie and line charts, while pie charts produced the least accurate results. Comparison of solid and textured patterns in graphs revealed that they are not an influencing factor in regards to information extraction. We also provide detailed comparison of current research findings against to prior research results.

Keywords

Information extraction, data representation, graphs, tables

INTRODUCTION

Decision Support Systems (DSS) are increasing being employed by organizations for their decision making activities. These systems depend upon various data presentation format to enhance information comprehensibility and value of the system (Carey and Kacmar 2003). Information presentations in graphs and tables are often viewed as being important tools for management as well as end-users. Of the presentation forms, "graphical charts are generally thought to be the superior reporting technique compared to more traditional tabular representations in decision making" (Jarvenpaa and Dickson 1988). According to Ives (1982) graphs can communicate as much as 100,000 times more effectively than statistical printouts alone. Naturally, data presentation should follow the nature of the data. For example, continuous data should be presented with line graphs, discrete data with bar charts, and so on. Despite the fact that presentation tools have been widely available for many years, developers and managers continue to depend on human factors research for guidance on how to present information more effectively (Hoadley 1990).

Prior research has provided insight on the effects of presentation forms; however, findings are inconclusive and often conflict with each other. For example, some researchers indicate that information can be extracted more accurately from graphs than tables (Jarvenpaa et al. 1985). While this may be true, others report that "graphs are no better than tables in presenting information" (Jarvenpaa et al. 1985). According to a survey by DeSanctis (DeSanctis 1984), out of 29 studies, 12 indicated that tables were better than graphs, 10 found no significant difference, and 7 concluded that graphs were superior. Much of these inconsistencies have been attributed to the variety of experimental tasks used (Davis 1989). According to Benbasat, Dexter, and Todd (1986), conflicting results often come from the inappropriate comparison of presentation forms. For example, since color has confounding effects it is impossible to discover differences when comparing monocolor tables to color graphs (Benbasat et al. 1986). These inconsistent and conflicting results have opened the door to further research in this area.

There are several possible reasons for the opposing outcomes of previous studies (Tan and Benbasat 1993), such as: problems with internal validity of the experiments (poor presentation designs, poor resolution of the medium used); not differentiating graphical forms such as line, bars, or pie charts; and mismatch between task and data representation forms. The contradictory results from previous studies and availability of great variety of data representation forms makes it difficult for end-users as well as designers to identify the most effective means of graphical information presentation. Thus, the purpose of this paper is to provide additional research in the area of human-factors, particularly with the effects of presentation form on information extraction tasks.

PRIOR WORKS

Before decisions can be made, information must first be extracted from presentation displays. The information extraction process is considered to be a cognitive task and involves extensive use of the human brain. As with Bailey's human processing model (Bailey 1989), conceptual models can help justify and assist with graphics design. According to this theory, humans use the right side of their brain for recognizing and processing graphic pictures. This recognition process illustrates the brain's extensive capabilities which can be tapped into by using graphics (Ives 1982). The second conceptual model described by Ives (1982) is called the "Human Information Processing Model". It says that humans "can handle considerably more inputs if the inputs are received on multiple channels" (Ives 1982). When the amount of information in these channels exceeds the limit (more than 7 per channel), users get overloaded and exhibit dysfunctional behavior. Ives (1982) defined dysfunctional behavior as errors and omissions.

Besides cognitive models, the human information processing system has been explained through the use of visual cues. Visual cues are triggered from mental images. They help humans decipher and retain information. Davis (1989) suggests that when information is presented in a graphical format, processing is done in a holistic fashion. This increases extraction ability and helps encode information into memory. When data is presented in a tabular format, humans process information in an analytical manner. If a graph does not enable the user to form images necessary to facilitate visual cues, performance will suffer. Presentation forms such as graphs are made up of several components such as color, labels, text, lines, and grids. All of these attributes are critical to the success of the display. Successful displays enable users to extract information accurately and with minimal effort. Forms that are not designed properly could produce adverse effects. For example, Jarvenpaa and Dickson (1988) note that using graphical charts with inconsistent scaling yield a poorer performance than those with consistent scaling.

For many years, "information systems researchers, statisticians, psychologists, and educators have investigated the relative advantages of various graphic and tabular forms of visual presentation" (Davis 1989). Of the research which exists today, few focus solely on the extraction process. In 1981, Ellen D. Hoadley (1990) made an important contribution to the area of human/computer interaction. Hoadley found that, when comparing monocolor to color, performance improved with color pie, bar, and tabular formats but not with line charts. When comparing graphs of the same color, Hoadley found no significant differences with the accuracy of pie, bar, and line charts. There did exist, however, a significant difference between graphs and tables; performance greatly decreased with the tabular format. In an earlier study similar to this, she compared graphs with cross-section patterns to those without and determined that out of the possible color treatments "solids produced the most effective and consistent results" (Hoadley 1990).

Another pivotal study was done by Larry R. Davis (1989), who set out to investigate "whether the most appropriate report form was a function of the information needed by the decision maker". Results from this study indicate that form of presentation and question complexity affect performance for information extraction tasks. Davis (1989) found that tabular displays resulted in performance superior or equal to that of the graphical charts (pie, line, and bar). In no case did the tabular displays result in poorer performance than the graphical presentation forms. Furthermore, the supremacy of tabular displays was not limited to any one level of question complexity, whereas performance for graphical charts was limited to questions with intermediate complexity. In summary, Davis's (1989) study showed that tabular displays are more effective for a wide range of questions, while graphical charts are only appropriate for a limited set of questions. Benbasat, Dexter, and Todd (1986) also examined the influence of information presentation on managerial decision making. Data was presented to the subjects in the form of monocolor and multicolor line graphs and tabular displays. The results from this study indicate that tabular formats are better for determining exact data values for computational purposes and graphical presentations are better for determining "promising directions in the search for an optimal solution" (Benbasat et al. 1986). The previous studies presented equivocal results that may be explained by experimental task differences. Despite the seemingly contradictory findings, these studies provide a framework for further research in the area of data display and computer-human interaction.

EXPERIMENTAL FRAMEWORK

The objective of the current study was to examine the effects of presentation form (graphic and tabular) on decision making tasks that involve information extraction. The experimental framework consisted of a 4 x 2 (presentation form x pattern) factorial design which provided for controls and quantitative measurement. Subjects were placed in a control situation in which they answered questions pertaining to either a graphic or tabular presentation display.

Environment

Seven applications, consisting of 14 screens each, were written to accommodate the presentation forms (solid bar chart, pattern bar chart, solid line chart, pattern line chart, solid pie chart, pattern pie chart, and tabular display). Each application

was programmed to capture completion times and user responses. Monitor brightness, color saturation, and contrast were directly controlled by the subjects. The physical environment was also controlled by the subjects in terms of seat height, distance to keyboard and monitor, and viewing angle of monitor.

Variables

The independent variables were presentation form and color texture: solid and cross-section pattern. The control variables were the information set and presentation questions. These variables were controlled by using an information set and group of questions supported by prior research (Davis 1989; Hoadley 1990). The group of questions, total of 10, represented a variety of complexity levels. The questions used in the experiment were derived by the experimenters based on the question set obtained from the Hoadley study (Hoadley 1990) and the Davis study (Davis 1989).

The presentation forms were displayed in four types: bar, pie, line, and tabular. Each presentation form represented a set of time-series data defined as data which shows "changes over time in single quantities or sets of quantities" (Ives 1982). It was chosen because "75% of the information presentations used for business are time-series in nature" (Hoadley 1990). The data used for the current experiment was taken from the research by Hoadley (1990). Bar and line charts were chosen for the experiment because they are considered to be standard forms for representing time-series data (Davis 1989). Pie charts, while not well-known for their use with time-series data, were used because of their common and extensive use in business reports (Davis 1989). Tabular forms were chosen because they represent the primary alternative to graphs for displaying information (Davis 1989).

The information presentations were displayed sequentially on a monitor. Monitors that were used for this experiment were Cathode Ray Tube (CRT) monitors. Colors for the bar, line, and pie charts were red, white, green, and yellow on a black background (Hoadley 1990). The bar, line, and pie charts were displayed with solid and cross-section patterns. The cross-section patterns were similar to those used by Davis and Hoadley (Davis 1989; Hoadley 1990). The colors used with the cross-section patterns were identical to those used for the solid formats. The tabular form was also presented in color. The rows were displayed in red, white, green, and yellow respectively. According to Hoadley (1990), displaying tables in color helps facilitate a more comparable measure between it and the graphical forms. The legend, title, and question for each presentation form were displayed in cyan.

The dependent variables were (1) response accuracy and (2) completion time. Response accuracy refers to the total amount of correct responses received from each subject. Completion time refers to the total amount of time taken to complete 10 questions. According to Hoadley (1990), accuracy and time are widely regarded as being important indicators of mental activity.

DATA COLLECTION

Subjects

Seventy-one volunteers between the ages of 20 and 39 participated in the experiment. Forty-seven subjects were male and 24 were female. Subjects were randomly selected for each group. In a pre-questionnaire, 68% percent of the subjects indicated they were frequent or occasional users and the remaining 32% indicated they used charts either seldom or never.

Procedure

The experiment consisted of subjects working through a series of 10 questions appearing sequentially. Each question pertained to the same set of time-series data in either graph or tabular form. Five of the questions required the subject to enter A, B, C, or D as their response. The remaining five questions required the subject to answer 1980, 1981, 1982, 1983, 1984, 1985, 1986, or 1987. If the subject did not enter one of the possible choices, an error message appeared asking her/him to press <ENTER> and try again. After the subject entered his/her answer to a question via the keyboard, the screen cleared and the next presentation display appeared.

Prior to viewing the presentation material, subjects were asked to provide demographic information such as vision, age, education level, gender, and chart usage. After subjects provided the desired demographic data, they were given a test for color blindness. This test consisted of a screen display of colors to which he/she entered the name of each color they saw. If the results indicated that the subject was unaware of the colors used by the experiment, his/her resulting data was excluded from the post-analysis. Upon completion of the color awareness test, subjects were given a set of instructions. Similar to the Davis (1989) study, subjects were informed that (1) there were no time limits, and (2) that speed and accuracy were equally important. Subjects were also given a blank sheet of paper for use with problem solving. Using this sheet was optional.

RESULTS OF DATA ANALYSIS

The primary data analysis was performed using analysis of variance (ANOVA) in order to determine the (1) main effect of texture – cross-section pattern vs. solid formats and (2) main effect of graphic type – pie, line, and bar. Additional data analysis included tests to determine if significant differences existed between the various graph types – pie, line, and bar. Post Hoc tests were chosen as the method for comparing graphs with tabular displays to control for repeated analyses. Since demographic data was collected during the experiment, correlations among characteristics such as age, gender, education level, and chart usages were also included in the analysis. A probability factor limit of 0.05 was chosen for use in determining if a significant difference existed and effect size (r) was also calculated. During an initial review of the data, some subjects were omitted from the post-analysis. Data gathered from 3 subjects who were color blind and 2 other subjects whose vision was not 20/20 (either natural or corrected) were removed.

Graphs vs. Tables – Completion Time

An analysis of variance (ANOVA) was done to determine if a significant difference existed with completion times for graphic versus tabular displays. According to the ANOVA results, there was a significant difference between the completion time for graphs and tables ($F_{(6, 64)} = 3.29$, $p < 0.05$, r = 0.22). A Student-Newman-Keuls test indicated that (1) bar charts took significantly less time to complete than tabular displays, (2) no significant difference existed between tables, pie, and line charts, and (3) no significant difference existed between pie, line, and bar charts. Analysis suggests that subjects took significantly longer to complete 10 questions with tabular displays (mean = 9.811 minutes) than with solid bar charts (mean = 6.061 minutes). It also implies that completion times for pie charts (mean = 8.426 minutes) were slightly higher than line charts (mean = 7.997 minutes).

Graphs vs. Tables – Response Accuracy

An analysis of variance (ANOVA) was done to determine if a significant difference existed with the accuracy of graphs versus tabular displays. The ANOVA results indicated a significant difference ($F_{(6, 64)} = 8.13$, $p < 0.05$, r = 0.34). Student-Newman-Keuls test indicated that (1) pie charts were significantly less accurate than bar, line, and tabular displays, (2) bar, line, and tabular displays were not significantly different, and (3) no significant difference existed between line graphs and pattern pie charts. Analysis suggests that tabular displays result in significantly higher scores than pie, line, and bar charts. It also suggests that pie charts yield significantly lower scores (mean = 5.900) than line (mean = 7.100), bar (mean = 7.761), and tabular displays (mean = 8.300). It can be concluded, therefore, that information can be extracted more accurately from line, bar, and tabular displays than pie charts.

Comparison of Graphs – Completion Time

An analysis of variance (ANOVA) was done to determine if a significant difference existed with completion times for the different graph types (bar, line, and pie). The ANOVA results showed a significant difference was present ($F_{(2, 55)} = 5.38$, $p < 0.05$, r = 0.3). A Student-Newman-Keuls test indicated that (1) pie and line charts took significantly longer to complete than bar charts, and (2) no significant difference existed between pie and line charts. Analysis suggests that information can be extracted significantly quicker from bar charts (mean = 6.0619 minutes) than line charts (mean = 7.99 minutes) and pie charts (mean = 8.211 minutes).

Comparison of Graphs – Response Accuracy

An analysis of variance (ANOVA) was done in order to determine if a significant difference existed between the accuracy of bar, line, and pie charts. The ANOVA results indicated a significant difference with the accuracy of the various graph types ($F_{(2, 55)} = 15.29$, $p < 0.05$, r = 0.47). A Student-Newman-Keuls test indicated that (1) scores for bar and line charts were significantly more accurate than those with pie charts, and (2) there was no significant difference between response accuracy for bar and line charts. Analysis suggests that bar and line charts produce significantly higher scores (mean = 7.43) than pie charts (mean = 5.90). It can be concluded, therefore, that information can be extracted more accurately from bar and line charts than pie charts.

Texture – Completion Time & Response Accuracy

The ANOVA results showed no interaction effect between group and texture. The ANOVA also showed no significant difference with the completion time ($F_{(1, 55)} = 0.05$, $p = 0.8195$) and accuracy score ($F_{(1, 55)} = 1.40$, $p = 0.2421$) for each texture. A Student-Newman-Keuls test was done on the dependant variable "completion time". Results of the Student-Newman-Keuls test indicated that the average completion time for graphs with cross-section patterns was 7.5429 minutes,

and 7.3980 minutes for solid formats. This suggests that cross-section patterns neither deter nor enhance extraction speed. A Student-Newman-Keuls test was also performed on the dependant variable "response accuracy". Results of the Student-Newman-Keuls test indicated that solid and cross-section patterns were not significantly different. Cross-section patterns produced an average score of 7.0968 (out of 10), while solid textures yielded an average score of 6.7667. This suggests that cross-section patterns neither deter nor enhance extraction ability. It can be concluded, therefore, that neither time nor accuracy are significantly impacted when cross-section patterns exist.

Demographic Data

The following demographic data was collected from each subject: age, gender, education level, vision, and chart usage. Correlation analysis of chart usage and education level indicates that as education level increased, so did chart usage (P = 0.0047, R = -0.33201). In other words, subjects with higher education levels used charts more frequently than those with lower education levels. This was not surprising, since most people with higher education levels seem to have professional careers which require the use of graphical and tabular displays.

DISCUSSION

The following paragraphs provide a detailed comparison of current experimental findings with prior research results. The current experiment and most prior research (Davis 1989; Hoadley 1990) agree that graphs and tables are significantly different when it comes to response time. The current experiment showed that it took significantly longer to extract information from tables than graphical charts. This was not surprising since most subjects viewing tables tended to use scrap paper to help them solve problems. Using the scrap paper caused subjects to draw away from the monitor, thus taking more time to complete the questions. Subjects viewing graphical charts took less time because they did not divert from the monitor. Instead, they used estimation and educational guesses to solve the problems. Although these assumptions stand to reason, Hoadley (1990) and Davis (1989) report findings differ from the current experiment. They report that information can be extracted more quickly from tabular displays than graphical charts. In Hoadley's (1990) experiment subjects took (on the average) 44 seconds to answer 8 questions with tabular displays. With graphical charts, they took (on the average) 53.33 seconds. Hoadley (1990) claims that these results are consistent with literature regarding the use of color and alphanumeric data on search-and-location tasks.

When comparing the accuracy of tables versus graphs, the current experiment showed that tabular displays produce more accurate results than graphs. This was not surprising, since subjects were given exact numeric values. With graphs, subjects tended to guess thereby leaving room for more error. Davis (1989) reported results similar to the current experiment; that tables were superior to graphs. However, according to Hoadley (1990), tables produce lower scores than graphs. Hoadley (1990) attributes the decreased accuracy of tables to the confounding effects of color. Findings from Hoadley (1990) suggest that the benefits of usage of color in graphs normally found with alphanumeric data did not apply for time-series data (used in the current experiment).

The current experiment and prior research also compared the accuracy of various graphical charts (pie vs. bar vs. line). Results from the current experiment and findings from Davis (1989) both showed a significant difference with the various charts. This implies that certain graphical formats, combined with certain types of data, directly impact information extraction. Hoadley (1990), on the other hand, found no significant difference between pie, line, and bar charts. This was surprising since the presentation forms used in Hoadley's (1990) study were similar to the ones used in the current experiment. Hoadley (1990) claims that finding no significant difference may have been the result of a ceiling effect. Of the significant differences found with accuracy, the current experiment indicated that pie charts were significantly less accurate than bar and line charts. This result was consistent with Davis's (1989) study which showed a decrease in accuracy when pie charts were used. It also justified conclusions from Jarvenpaa and Ives (Ives 1982; Jarvenpaa and Dickson 1988) which state that pie charts do not work well with time-series data.

When comparing response time for each graphical chart, the current experiment indicated that bar charts take significantly less time to extract information from than line and pie charts. These results conflict with both Hoadley and Davis (Davis 1989; Hoadley 1990). Hoadley (1990) showed no significant difference with response time. Davis (1989) reported that bar charts take longer to extraction information from than pie and line charts. Lastly, the current experiment showed that including texture in graphs does not deter or enhance extraction ability. However, Hoadley (1990) found that performance was significantly lower with graphs containing cross-section patterns than those with solid formats.

CONCLUSION

Various prior research works has focused on the effects of presentation forms on information extraction tasks. Most of these research used either strictly monocolor graphs or compared monocolor to color treatments. The research described in this paper is an investigation of data display and human performance interaction relevant to decision making which used only color treatments. It compared several presentation forms and used both solid and cross-pattern designs. Measures were taken to capture and quantify extraction timings and response accuracy. The basic findings from the experiment suggest that extraction ability is dependent on presentation form and the task at hand. Although some prior research findings (Benbasat et al. 1986; Davis 1989; Hoadley 1990; Jarvenpaa and Dickson 1988) agree with the current experiment, many results are very different. The fact that current experimental results conflict with prior research findings does not imply that prior research findings are invalid. Nor does it suggest that current research findings are invalid. It simply implies that the tasks for each experiment were different thereby resulting in different outcomes. "Task" pertains not only to what the subject actually does, but also the surrounding area in which the activity occurs. Even though the current experiment used the same question set as Hoadley (1990), it did not use all of the associated questions. Instead, the current experiment used questions derived from a variety of other research works. Furthermore, the software packages used to develop graphic and tabular displays were different among the various prior researches. This implies that variations in shade, hue, brightness, and contrast also contributed to conflicting results.

Suggestions for Further Research

The current study analyzed four types of presentation forms: bar, line, pie and tabular. This represents only a small portion of the graphical formats available today. The current experiment did not analyze question complexity or information recall. Nonetheless, it provided information on what formats are favorable for use with time-series data, and which ones are not. Researchers should continue investigating how graphics can be used to improve decision making, this is particularly of importance due to proliferation of usage of Internet-rich applications. Such investigations also should conduct experiments that are long enough to identify the affects of learning. Most research studies to date have been ad hoc, one-shot experiments. These types of experiments lend themselves to less validity than those done over periods of time. Along with learning, future research should also concentrate on validating the guidelines outlined in current books and articles. Using a standard set of guidelines will help validate prior research and reduce inconsistencies among experiments. Finally, more research is needed regarding the relationship between graphs and question complexity as prior research suggests that performance differs depending on presentation form and question type (Davis 1989).

In this paper, we address an old problem of identifying best presentation form to allow maximum information extraction to aide efficient decision making. The findings from the experiment indicate that this problem is still unresolved and needs to be revisited. Given that in the current environment, decision makers face more complex problems, have lesser time in hand, and use wide variety of presentation forms, it is critical to understand effects of presentation forms on the efficiency and comprehensibility of information extraction.

REFERENCES

1. Bailey, R.W. *Human Performance Engineering* Prentice Hall, 1989.
2. Benbasat, I., Dexter, A.S., and Todd, P. "The influence of color and graphical information presentation in a managerial decision simulation," *Human-Computer Interaction* (2:1) 1986, pp. 65-92.
3. Carey, J.M., and Kacmar, C.J. "Toward A General Theoretical Model Of Computer-based Factors That Affect Managerial Decision Making," *Journal of Managerial Issues* (15:4) 2003, p. 430.
4. Davis, L.R. "Report format and the decision maker's task: An experimental investigation," *Accounting, Organizations and Society* (14:5-6) 1989, pp. 495-508.
5. DeSanctis, G. "Computer Graphics as Decision Aids: Direction for Research," *Decision Sciences* (15:4) 1984, pp. 463-487.
6. Hoadley, E.D. "Investigating the effects of color," *Communications of the ACM* (33:2) 1990, pp. 120-125.
7. Ives, B. "Graphical User Interfaces for Business Information Systems," *MIS Quarterly* (6:1) 1982, pp. 15-42.
8. Jarvenpaa, S.L., and Dickson, G.W. "Graphics and managerial decision making: research-based guidelines," *Communications of the ACM* (31:6) 1988, pp. 764-774.
9. Jarvenpaa, S.L., Dickson, G.W., and DeSanctis, G. "Methodological Issues in Experimental IS Research: Experiences and Recommendations," *MIS Quarterly* (9:2) 1985, pp. 141-156.
10. Tan, J.K.H., and Benbasat, I. "The effectiveness of graphical presentation for information," *Decision Sciences* (24:1) 1993, p. 167.