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2D vs. 3D Graphing Styles: A Comparison of the Accuracy of Reader Perceptions for 2D vs. 3D Graphs*

Andrew Russell and John S. Bielewicz
Robert Morris University

Students and researchers often choose a graphing style for the display of data based on the style's aesthetic, rather than functional, qualities. Three-dimensional graphs may look more professional, but use of this style may negatively influence the accuracy of a reader's perception of the presented information. The purpose of this study is to test perceptual accuracy of subjects when reading graphs rendered in a 2-dimensional versus a 3-dimensional graphing style. The test was given to students via two mediums: paper and electronic. Results were analyzed to determine the degree to which accuracy is affected based on the style of graph used and the medium in which it is presented.

Over the past several years at the WPUPC, we have noticed that many groups use 3D graphs to present their data (see Table 1). We have often found that this style of graph is difficult to read compared to 2D graphs. Our observations have been supported by some research (e.g., Barfield & Robless, 1989; Hughes, 2001). These difficulties seem to stem from a conflict between 3D depth cues and the method by which readers should actually (and accurately) interpret 3D graphs. However attractive these graphs may be, it seemed to us that they were much more difficult to read.

Table 1. Use of 3D graphs during previous WPUPCs.

Conference	3D	2D	Both	None	N/A	Total
Mercyhurst (2003)	22%	50%	5%	19%	5%	64
Allegheny (2004)	17%	61%	2%	17%	5%	66
Chatham (2005)	15%	57%	1%	23%	5%	66

We do not know exactly why so many WPUPC presenters use this style of graph; although there is some sense of aesthetic pleasantness to the more elaborate 3D as opposed to 2D graphic. Nor is the apparent preference for 3d graphs unique to WPUPC presenters (cf. Fisher, Dempsey, & Marousky, 1997). The fact that it is the installation default graph type in some programs (e.g., Microsoft Word) might have something to do with it. Therefore, one goal of the present study was to measure the relative effectiveness of 3D and 2D graphs in conveying the data values depicted.

With the increase in sophistication of many computer programs, what was at one time very time consuming to do (e.g., draw 3D graphs) has become almost effortless. There has even been a push to move data collection to more automated web-based systems (e.g., Websurveyor). While there are potential benefits to automating research, there is very little evidence to make the case that on-line research methods are better than, worse than, or equivalent to on-paper (or in-person) methods. A second goal of the study was to use this research as a test of the effectiveness of in-person compared with on-line approaches to data collection.

Methods

Participants

For the on-paper version of the present study, 50 Robert Morris University (RMU) male and

*Correspondence concerning this research should be addressed to Stephen T. Paul, 311 Massey Hall, Robert Morris University, 6001 University Blvd., Moon Township, PA 15108-1189. E-mail: paul@rmu.edu.

female undergraduates were tested. For the on-line portion of the study, 35 RMU males and females were tested. All volunteers received course credit.

Materials

The on-line and on-paper stimulus sets were identical in content. Each set consisted of 10 graphics, the first two of which were for practice (one simple 2D graph and one simple 3D graph) and data from these were not included in the final analyses. The remaining eight graphs were divided into two sets: Complex and simple (see Figures 1 and 2 for examples). Complex graphs were those containing two independent variables while the simple graphs contained data sets based on a single independent variable. Each set alternated between 2D and 3D versions of the graph across subjects such that no subject saw the same data set in both a 2D and 3D version.

Figure 1. Example of a simple 2D graph used in the present study.

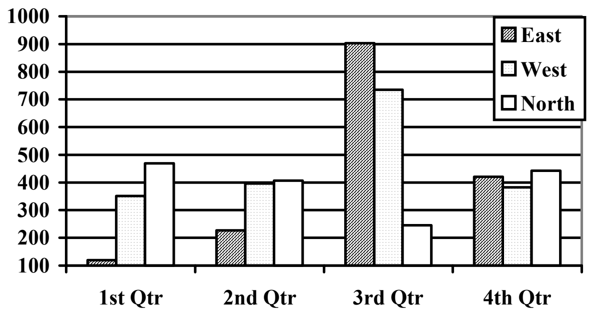
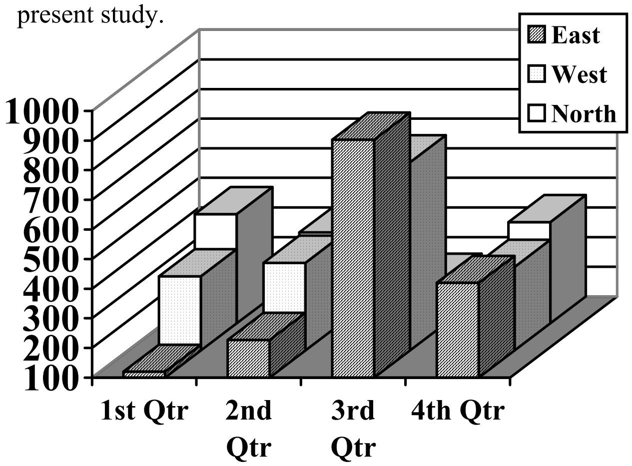


Figure 2. Example of a complex 3D graph used in the present study.

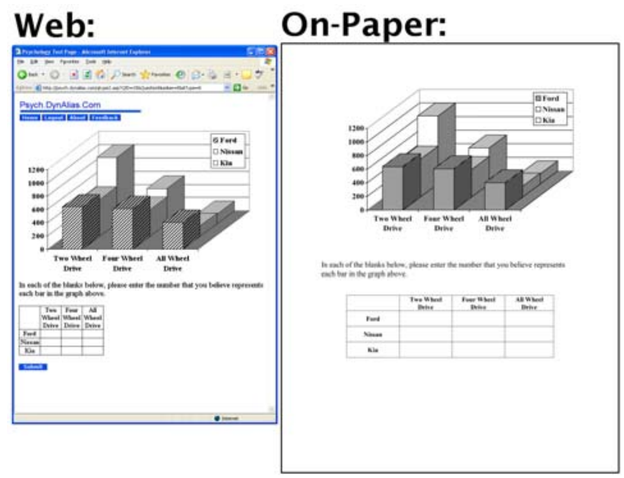


Procedure

Participants in the on-paper condition were asked to examine one graph at a time and record the values of each graphed data point in a labeled table below each graph. There was no set time limit for completing the packet and once packets were turned in the experimenter made a note as to whether the packet was completed by a male or a female (to guard against stereotype threat issues).

The web survey was a direct copy of the paper survey (see Figure 3), although subjects were required to register online to complete it. Each graph was displayed on screen, and each subject was required to type the data values into the table below it. The web forms did not allow participants to enter non-numeric text. If the submit button was pressed before all answers were filled in, the server returned an error and directed the user to the previous page. The use of a web survey also enabled the monitoring of response times.

Figure 3. Examples of a complex 3D graph used in the on-line (web) and in-person (on-paper) portions of the present study.



Results

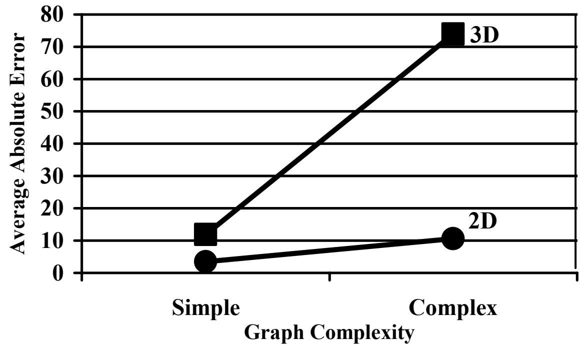
For all analyses, an alpha level of .05 was used. A 2 (Format: web/paper) x 2 (Depth: 2D/3D) x 2 (Complexity: simple/complex) mixed factor analysis of variance was performed. The between subjects factor was Format, and the dependent variable was the mean absolute differences between each subject's data-point guesses and the actual data for each graph.

Main effects for Depth and Complexity were found, however both were involved in a significant Depth by Complexity interaction, $F(1, 83) = 232.006$, $p < .01$, which can be seen in Figure 4. No other effects were significant (all $p > .25$).

An additional 2 (Depth: 2D/3D) x 2 (Complexity: simple/complex) within subjects analysis of variance was performed on average response times (number of seconds spent on a graph divided by the number of data points for that graph).

The only significant finding was a main effect for Complexity, $F(1, 34) = 53.598$, $p < .01$, in which complex graphs required an average of 15.9 seconds per data point to complete, while simple graphs required only 9.0 seconds per data point to complete.

Figure 4. Interaction of depth with graph complexity.



Discussion

One clear finding from the present study is that the outcomes did not depend whatsoever on the method of data collection used (on-paper versus on-line). Therefore, the present study provides indirect support for the use of automated on-line data collection techniques by providing no evidence of differences between on-line and off-line techniques.

A second clear finding is that errors in reading a graph increase a great deal when moving from 2D to 3D presentation formats. The error is particularly severe when graph complexity is increased.

The major reason that a 3D graph is more difficult to read is because we can choose to read a 3D graph in several seemingly sensible, yet incorrect, ways (see also Zacks, Levy, Tversky, & Schiano, 1998). Below (Figures 5 through 8) are some of the likely errors made by participants.

Figure 5. Using the back of a 3D column traced to the front of the graph resulting in a misreading of 159 (correct = 146).

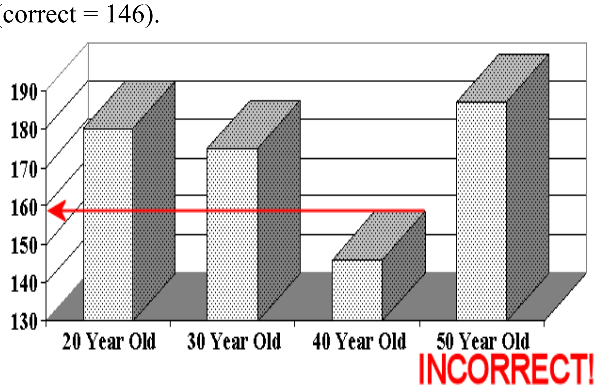


Figure 6. Using two opposite sides of a bar (misread as 110; correct = 236).

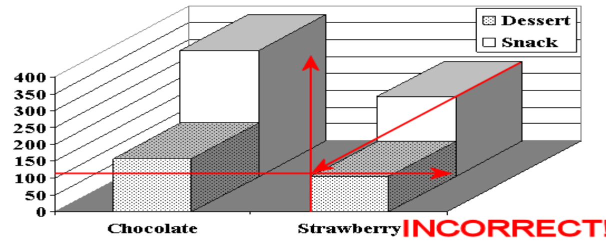


Figure 7. Connecting line from back of 3D bar to side wall at the wrong point (misread as 250; correct = 236).

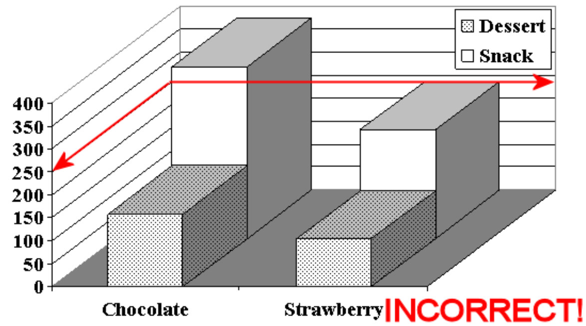
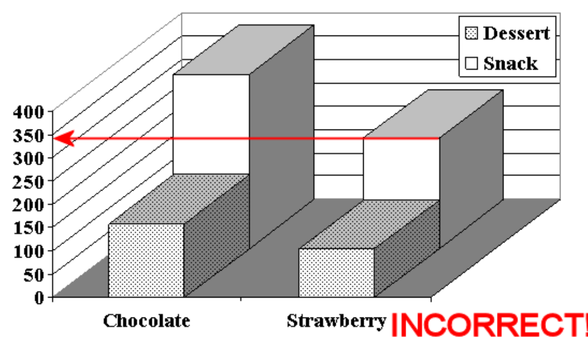


Figure 8. Tracing front of rearward bar to front of graph area results in a misreading of 347 (correct = 236).



Graphs making use of misleading depth cues may look nicer than 2D graphs, but they can result in severe errors of interpretation (especially as complexity is increased). Based on the present findings it seems worthwhile to use web-based techniques to study the most common heuristics used to read graphs as well as the relative advantages and disadvantages of other types of graphic formats (e.g., pie charts). Also, it might be worth considering 3D graphs that intentionally mislead consumers (e.g., media, political, and business use of such graphs).

The correct way to read a 3D graph is to either use the back of the bar against the back of the chart or to line up the appropriate corners of each bar and extend the line to the side of the graph with data results (see Figure 9 through Figure 11).

Figure 9. Tracing the top edge of a 2D bar to the left edge (ordinate) should result in a fair reading of 236.

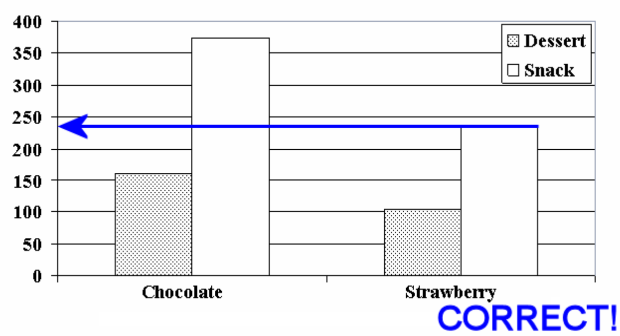


Figure 10. Projecting a side edge of a rearward bar to the front corner axis of its front most bar; then to the left edge (ordinate) should result in a fair reading of 236.

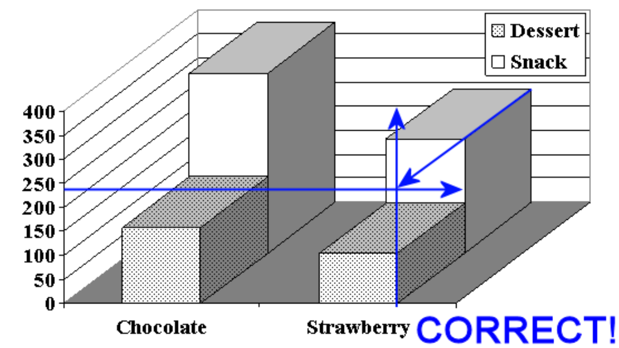
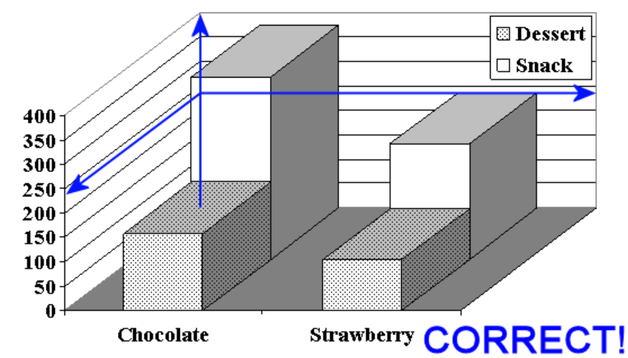


Figure 11. Projecting the back edge of a rearward bar to the rear reference lines, then around to the left edge (ordinate) should result in a fair reading of 236.



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