Improving the Accessibility of Graphs for Users who are Blind

Elaina Boytor
DePaul University
243 S Wabash
Chicago, IL 60614 USA
eboytor@gmail.com

Aarti Israni
DePaul University
243 S Wabash
Chicago, IL 60614 USA
aisrani2@gmail.com

Casey Hudetz
DePaul University
243 S Wabash
Chicago, IL 60614 USA
caseymhudetz@gmail.com

Nathan Petts
DePaul University
243 S Wabash
Chicago, IL 60614 USA
nbpetts@gmail.com

Abstract

Graphs are a common method for communicating information to audiences, but are inaccessible to users who are blind. This study explores the challenges faced by these users through usability tests of graph descriptions with varying levels of detail. Users then answered questions about the graph content and gave satisfaction scores. We also conducted interviews with participants about their prior experiences with graphs. Overall, participants' comprehension and satisfaction increased directly with the graph description level. We found that although screen readers are the tools primarily used to access graphs, some graphs are inaccessible by screen readers or have text alternatives that provide limited or no descriptions. Graph descriptions must include the graph type and attributes as well as the context of use for each graph. Descriptions must not burden users with remembering information or frustrate them with repetitive data. This paper proposes description guidelines for designers to create accessible graphs.

Author Keywords

Human Computer Interaction; Accessibility; Blind; Visually Impaired; Graphs; Assistive Technologies; Descriptive Alt Text.

ACM Classification Keywords

K.4.2 Social Issues (Handicapped persons/special needs)

Introduction

Graphs are a common method used to disseminate numerical information to the public. Determining a graph's meaning requires that a reader can access the information the graph contains. For example, a reader must (a) perceive the data, (b) distinguish multiple groups of data (e.g., lines on a line graph), (c) extract comparisons, (d) have a sense of the display area, and (e) notice any important aspects of the data such as inflection points, intersections, axes, and origins [2]. This poses a challenge for users who are blind; they cannot use sight to perceive these attributes.

In a meta-analysis, Paneels (2010) reported that haptic devices have been successfully used to convey information about a graph to users who are blind or partially sighted [2]. Research has also demonstrated that multi-modal devices that use both audio and haptic feedback can increase the accuracy of graph interpretation by users who are blind [6, 7]. Specifically, Wu and Brewster (2012) found that haptic feedback can provide users with the ability to navigate a graph and compare different bar heights. While audio can provide users with an overview of the graph, a way to confirm exact values, and a method to analyze data trends [7]. Although audio and haptic methods are helpful, they are not commonly available. Therefore, we decided to focus on how to improve graph accessibility for a common technology. In other words, can we improve written descriptions and develop guidelines for web developers and designers when presenting graphs in web-based technologies for screen readers?

In this study, we investigated written description requirements to enhance the accessibility to basic graphs (e.g., bar and line graphs etc.) for people who are blind. These are graphs that readers often encounter in news articles and social media posts.

We explored the following research questions: (1) how do users who are blind currently interact with graphs? (2) What challenges do users who are blind currently face when encountering graphs? (3) How can designers improve written descriptions for users who are blind?

Methods

In the next sections, we describe the participants, data collection, and data analysis of our study.

Participants

We recruited four participants for the study through the Chicago Lighthouse, friends, and family. All participants were blind and lived in Chicago. To take part in the study, participants needed to be familiar with common web accessibility technologies and have a general understanding of bar and line graphs. This ensured that participants would not require an orientation or introduction to graphs during the sessions. The breakdown of the participants was as follows:

Pseudonym	Age	Gender
Anna	66	F
Betty	26	F
Carl	38	M
Denise	67	F

Table 1: Breakdown of participant demographics

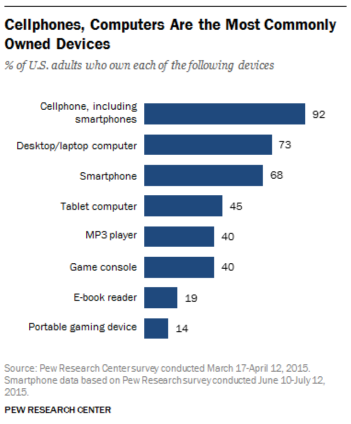

Figure 1: “Graph 1” – Used for lowest level of description.

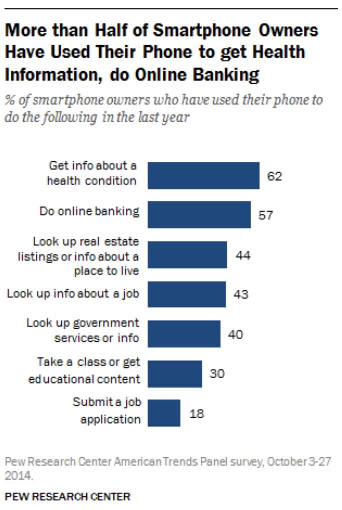

Figure 2: “Graph 3” – Used for highest level of description.

Data collection

We conducted a two-part study: (1) usability tests on three graph descriptions that we created and (2) interviews about their experiences with graphs. We obtained taped consent from each participant before conducting the sessions.

To create our graph descriptions, we used three graphs from the Pew Research Center website (see [1, 3, 4]) that were similar in complexity (the content/topic of the graphs, the number of variables, and the layout). The amount and type of information provided for each graph varied from low to high. The lowest level of description included an overview of the graph. For example, “This graph shows the percentage of devices owned by US adults based on a survey conducted from March 17th to April 12th of 2015. The graph shows that most commonly used devices are cellphones and the least commonly used devices are portable gaming devices.” The medium level description included the graph overview and added the values per category. The highest level of description included the graph overview and category values along with a description about the trends on the graph. After reading each description aloud, we asked the participants to answer four questions (based on the work of Yu [7] and Wall [5]) to assess their understanding of the graph content based on the level of description provided:

1. Are you able to describe the overall characteristics of the data? If yes: what are the overall characteristics?
2. Are you able to identify the greatest value? If yes, which has the greatest value?
3. Are you able to identify the smallest value? If yes, which is the smallest?
4. Are you able to identify which two items are the closest values? If so, which two items have the closest values?

We then asked the participants to rate the clarity of the descriptions provided for each graph based on a 5-point Likert scale. In addition, we asked participants about their experience with our graph descriptions, their technology use, their experiences when encountering graphs on websites, and demographics. Sessions were audio recorded.

Data analysis

We assessed the effectiveness and clarity of each graph description by tallying the correct answers to each assessment. We computed the average clarity rating across all participants and compared these for each graph.

Each team member individually extracted quotes from the transcribed interviews for common and salient themes. We pooled our data using an affinity diagram and identified common themes.

Findings

In this section, we describe the insights gathered from our user studies.

Understanding Graph Content through Graph Descriptions

All participants were able to provide a high-level overview of the graph based on each graph description provided except for the first description, which contained the lowest level of description. Upon hearing the first graph description, only two participants were able to provide a high-level overview. The graph

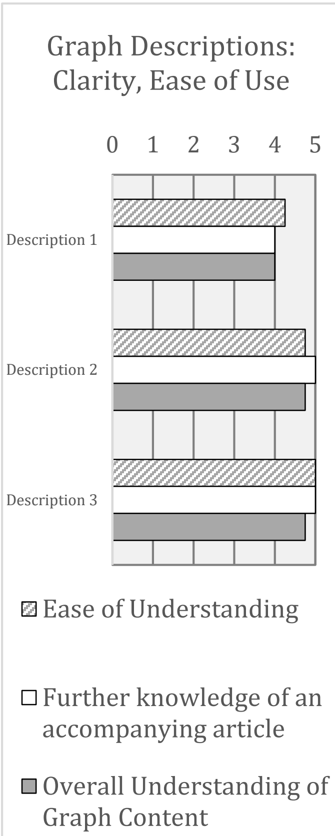

Figure 3: Results of satisfaction questions that followed each graph description. 1 is strongly disagree, 3 is neither agree nor disagree, and 5 is strongly agree.

description format had no impact on the participants' ability to identify the highest or lowest graph values; all participants answered questions about the highest and lowest values correctly for each graph description. Participants experienced the most difficulty identifying the categories with the closest values. However, the number of participants that answered this question correctly steadily increased from 0 to 2 as the graph description amount increased.

Graph Descriptions - Clarity, Ease of Use

Based on the average scores computed for the Likert satisfaction questions, the participants' ease of understanding the graph, overall understanding of the graph, and ability to further their knowledge about technology-based device use increased as the graph description amount increased (see Figure 3).

Qualitative Findings

We identified nineteen individual categories from the data gathered. These categories were then grouped into four themes: Technology Usage, Experience with Graphs, Challenges When Trying to Access Graph Descriptions, and Most Important Features in a Graph Description.

Technology Usage

All participants used mobile phones and computers on a daily basis. They used their phones to access social media, email, call people, browse the internet and check their calendars. Participants used their computers to check email, access social media, work on application forms and gather news. All participants used at least one accessibility device such as a screen reader and/or mobile voice-over. One participant mentioned using a recorder to capture, store, and access information such as names, addresses, music, books, and descriptions of real-estate.

Experience with Graphs

Participants had varied experiences with graphs. They interacted with graphs in paper and digital mediums within various settings including school, work, and as a hobby. Three participants mentioned specific tools or features they used to access graphs. These included Excel, JAWS Screen Reader, NVDA, Windowize, and alternative text. Participants reported positive and negative experiences accessing graphs. Two participants mentioned that Excel allowed them to navigate through the finer details of graphs. Some negative graph experiences reported by participants included nonexistent screen reader support, the lack of accessibility tools for graphs, and the limited description provided by screen readers. Anna told us that very often she encounters graphs in articles with text that just reads "This is a graph."

Challenges When Trying to Access Graph Descriptions

Participants experienced various types of challenges when accessing graph descriptions including the lack of spatial understanding, the burden of trying to remember a lot of information, and the challenge of sorting through repetitive data. Participants mentioned that if they had no prior exposure to graphs earlier in life, they might not understand the visual concept of the graph. Denise, who had seen bar graphs earlier in her life when she had partial vision, stated: "It just occurred to me that I know what I'm fishing for when you're talking. When I have someone who may not have that spatial learning you don't even have the concept so it's important to give people that position kind of thing." Three participants mentioned the burden of memorizing the information presented in a graph description. It was particularly challenging for participants to know what information they needed to memorize if the objective or context of the graph was not initially presented to them. Participants mentioned that some of the information presented in the graph descriptions was redundant, which contributed to their frustration of trying to sort through all the data.

Most Important Features in a Graph Description
Participants desired that graph descriptions included the type of graph, graph scope, objective or context of the graph, sections of distributed content, categories, values, and trends. Participants desired to know the type of graph (i.e. bar or pie). They also wanted a way to verify that the description covered all content present in the graph description. Participants felt that the objective or context that the graph was originally presented in was necessary for understanding which information needed to be gleaned. Participants expressed a desire to have graph descriptions broken down into sections that they could return to if they wished to review particular details about a graph; this is contrary to our graph descriptions that could only be repeated in full. Several participants expressed the need to have a synopsis of the overall trend the graph is trying to convey. Denise stated: “Just tell me the conclusions, and if you say there's a chart here that'll give you more detail but it's not going to be integral to what I want to know, which is the trend.”

Discussion
In this section, we outline three guidelines for designers to create more accessible graphs. Next we discuss limitations of our study and our plans for future research.

Graph Description Guidelines
First, designers should make the context of the graph clear in their description. When asking our participants to describe the trends of our graphs, many of them responded that it would depend on how the author intends to use the graph. For instance, a graph may serve to support an argument or to display detailed findings, neither of which we specified in our descriptions. Designers must explicitly state the graph’s purpose and context.

One way designers can provide context in graphs is by providing physical descriptions of the graph. Our descriptions did not include the physical dimensions of the axes or bars. Several participants indicated that they would have preferred to have some idea of what the graph actually looked like. Depending on the context of use, designers may describe the x and y axes, graph type, or shape of the data. Graphs used to support an argument may benefit more from vague descriptions of the graph type or shape of the data. Graphs displaying large ranges of data may benefit from more specific descriptions of the x and y axes. We should explore this distinction with further testing.

Second, designers must provide access to the graph’s data on demand. Our participants were able to successfully compare the exact figures we provided, but did not want us to re-read any data that they missed. We gave our participants the option to re-read the descriptions, but only one took it. Several participants noted having experience with Excel to access structured data. Designers must include raw data that breaks down the graph into sections with a clear hierarchy so that users can skip to different sections. This hierarchy must follow common accessibility techniques.

Last, designers must pay close attention to the cognitive load of their descriptions. All participants struggled to remember details in the graphs with long descriptions. Designers must follow best practices and techniques to increase memory retention and reduce cognitive load. These techniques include chunking information together, using clear declarative writing, and removing repetitive descriptions.

Limitation of the Study

Our study had several limitations. First, our participant size was small and, therefore, it is difficult to generalize our guidelines for all users who are blind. In addition, we provided graph descriptions that lacked context and, therefore, may not have been meaningful to our participants. This may have impacted our participants' ability to absorb the information presented in the graph descriptions.

Next Steps

In future studies, we would like to test conditions where participants interact with a graph that accompanies an article to understand the impact of the added context on the results. We would also like to use the guidelines we outlined above to see if the descriptions enhance the accessibility of graphs for users who are blind. Future testing would also benefit from a larger sample size.

References

1. More than Half of Smartphone Owners Have Used Their Phone to get Health Information, do Online Banking. (2015, March 31). http://www.pewinternet.org/2015/04/01/u-s-smartphone-use-in-2015/pi_2015-04-01_smartphones_03/
2. Paneels, S. (2010). Review of Designs for Haptic Data Visualization. IEEE Transactions on Haptics, 199-137.
3. Technology Device Ownership: 2015. (2015, October 29). http://www.pewinternet.org/2015/10/29/technology-device-ownership-2015/
4. The Demographics of Device Ownership. (2015, October 29). http://www.pewinternet.org/2015/10/29/the-demographics-of-device-ownership/
5. Wall, S. & Brewster, S., (2006). Feeling what you hear: tactile feedback for navigation of audio graphs. Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '06), 1123-1132. DOI=http://dx.doi.org.ezproxy.depaul.edu/10.1145/1124772.1124941
6. Weir, R., Sizemore, B., Henderson, H., Chakraborty, S., and Lazar, J. (2012). Development and Evaluation of Sonified Weather Maps for Blind Users. In P. Langdon, J. Clarkson, P. Robinson, J. Lazar, and A. Heylighen, (eds.) Designing Inclusive Systems: Designing Inclusion for Real-world Applications. London: Springer-Verlag, 75-84.
7. Yu, W., Brewster, S. (2003). Evaluation of multimodal graphs for blind people. Universal Access in the Information Society, 105-124.