Understanding Low Vision Graphical Perception of Bar Charts

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ABSTRACT

Bar charts are widely used for their simplicity in data representation, prompting numerous studies to explore and model how users interact with and perceive bar chart information. However, these studies have predominantly focused on sighted users, with a few also targeting blind screen-reader users, whereas the graphical perception of low-vision screen magnifier users is still an uncharted research territory. We fill this knowledge gap in this paper by designing four experiments for a laboratory study with 25 low-vision participants to examine their graphical perception while interacting with bar charts. For our investigation, we built a custom screen magnifier-based logger that captured micro-interaction details such as zooming and panning. Our findings indicate that low-vision users invest significant time counteracting blurring and contrast effects when analyzing charts. We also observed that low-vision users struggle more in interpreting bars within a single-column stack compared to other stacked bar configurations, and moreover, for a few participants, the perception accuracy is lower when comparing separated bars than when comparing adjacent bars.

CCS CONCEPTS

• **Human-centered computing → Empirical studies in accessibility**.

KEYWORDS

Low vision, Graph usability, Screen magnifier, Graph perception

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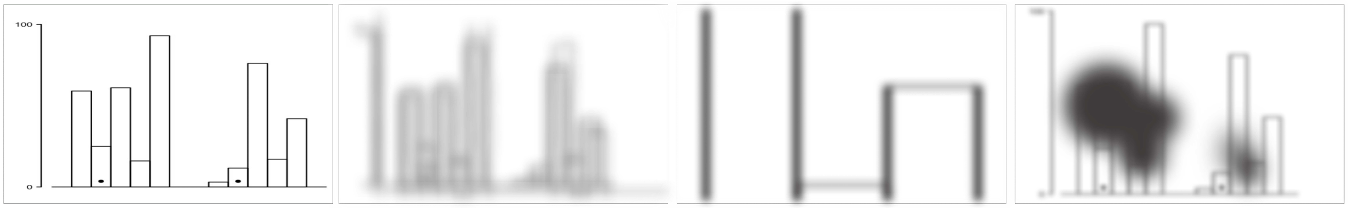
1 INTRODUCTION

Data charts have become a ubiquitous means of data representation online and in academic and professional environments due to their remarkable ability to condense and convey intricate data in a simpler format, facilitating swift and easy comparisons and data interpretation [11, 13]. Among popular data chart types, bar charts are a widely used type of visualization, especially for categorical data comparison, and serve as a tool for visualizing a range of data, including stock values, census figures, product sales, customer ratings, currency exchange rates, and hospitalization rates [20]. Considering the broad adoption of bar charts, it is crucial to enhance their usability for individuals with visual disabilities. To do this, we first need to understand how people with visual disabilities perceive and interpret bar charts.

There exist quite a few research works that have explored graphical perception and perceptual effort required by sighted individuals to interpret bar charts [5, 7, 10, 23, 30]. This understanding of graphical perception has influenced creation of better bar chart design guidelines for sighted users. Regarding perception of people with visual disabilities, existing works have all focused on blind users [3, 8]. The graphical perception of low-vision users is still an unexplored research area. In this paper, we conduct a preliminary study on this topic by examining how low-vision users perceive bar charts.

Low vision refers to visual impairment in one or both eyes that cannot be rectified with glasses, contact lenses, medication, or surgery [12, 25]. Low-vision conditions include central vision loss, peripheral vision loss, night blindness, and blurry vision [26], which can impact how these individuals decode visual charts. For instance, those with central vision loss may see distorted bars in a bar chart, while those with severe peripheral vision loss might only perceive one or two bars at a time, unable to scan ahead (see Figure 1). Another prominent characteristic of low vision is poor visual acuity (less than 20/70) [1]. These factors typically make low-vision users rely on screen magnifiers to clearly view the content, including charts [6, 21]. However, enlarging content introduces several challenges to people with low vision [22]. First, low-vision users often require varying zoom levels on standard desktop displays due to their different visual acuities based on their eye conditions. Second, insufficient magnification can result in noticeable blurring or smudging of the content. Third, the perception of charts can



(a) Sighted View (b) Blurred View (c) Magnified View (d) Vision Loss View

Figure 1: This figure demonstrates the examples of variations in bar chart perception between sighted individuals and those with low vision. The representations of low-vision perceptions are derived from descriptions by our study participants. (a) Bar chart as perceived by a sighted individual, (b) a blurred view as described by our low-vision participant, (c) a magnified view of the chart, and (d) bar chart as observed by an individual with central vision loss.

differ at different zoom levels. Fourth, with a continuous shift in focus during panning, the users may need to patiently wait until stabilization, brought forth by the accommodation reflex [16].

To examine graphical perception, we conducted a user study with 25 low-vision participants. The study revealed many insights, notably, distractors (i.e., bars not directly relevant in a comparison task) played an important role in the overall graphical perception of low-vision users. Specifically, tall distractors were found to considerably elevate the error rates, contradicting prior findings with sighted users where tall distractors played a minimal role [23]. Also, perception errors were higher in case of adjacent bars in the same column of a stacked bar chart compared to the non-adjacent bars, an observation that also contradicts prior findings with sighted users who found it easier to compare adjacent bars [23].

In sum, this paper contributes insights derived from a user study with low vision participants assessing their graphical perception abilities. These insights can potentially serve as the basis for formulating future chart design guidelines and systems that accommodate the needs of low vision users, similar to how prior perceptions studies with sighted people [5, 23] have influenced design of more usable charts [19, 31].

2 RELATED WORK

2.1 Visual Perception of Low-vision Users

Prior research has studied the effects of factors such as color and font on the visual perception of people with low-vision, with particular emphasis on their reading abilities [2, 14, 15, 27, 29]. For example, Wurm et al. [29] compared colored images with their achromatic counterparts. This study involved 16 low-vision participants, focusing on their ability to discern images of everyday food items. A two-way ANOVA analysis indicated that both color and acuity significantly influenced reaction time. However, no notable correlation between color and acuity was found.

In a comprehensive study, Mansfield et al. [15] investigated the influence of font types on reading performance by comparing sighted users (50 participants) with low-vision users (42 participants). Their findings revealed that reading acuity was notably reduced with the Times New Roman font as opposed to the Courier font, showing a difference of 0.09 logMAR (i.e., a method used to measure visual acuity based on the logarithm of the Minimum Angle of Resolution (MAR)) for low-vision users. For individuals experiencing central vision loss, the critical print size (the smallest print size read at optimal speed) was significantly larger in Times New Roman compared to Courier, with a difference of 0.07 logMAR. Furthermore, reading speeds among the low-vision participants were approximately 10% slower when using the Times New Roman font than when using the Courier font. Similar to these works, other research primarily addresses the reading behavior of low-vision users [2, 26].

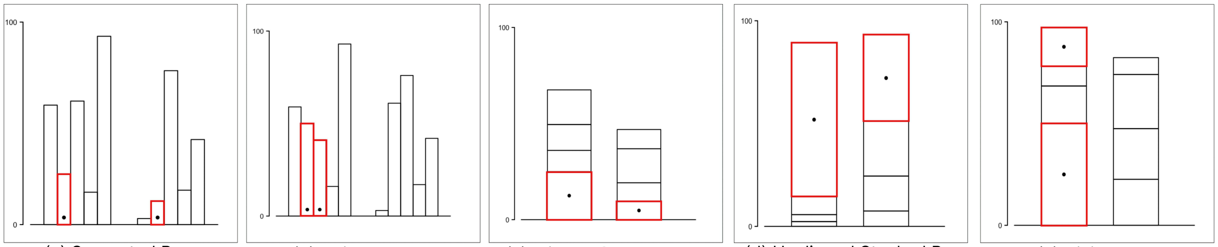
However, all these research works only address the reading behavior of low-vision users; research involving understanding the perception of charts for low-vision users is still an uncharted research territory, which we intend to fill in this paper.

2.2 Graphical Perception of Charts

Prior research has delved into understanding the graphical perception of sighted users [5, 7, 10, 18, 19, 23, 30]. In a seminal work, Cleveland & McGill [5] conducted a bar chart experiment to explore the proficiency of sighted individuals in estimating the length ratio of two bars in a bar chart. Participants were presented with bar charts in five distinct configurations and tasked with estimating the height of the shorter highlighted bar as a percentage of the taller reference bar's height. The study also included a comparison between aligned and unaligned stacked bar charts. They observed that charts where bars shared a common baseline, such as Adjacent Bars, Separated Bars, and Aligned Stacked Bars, had more accurate estimations than charts where the bars were not aligned, like in Unaligned Stacked Bars and Divided Bars (see Figure 2 to distinguish between types of bars in charts).

Talbot et al. [23] conducted additional experiments to delve deeper into the results identified by Cleveland and McGill [5]. While confirming previous findings, their results validated the increased challenge in comparing separated bars relative to adjacent ones, coining this observation as the 'separation effect'. They further explained Cleveland and McGill's results by stating that the separation effect primarily exists due to the distance between bars used for comparison and the overall visual clutter in bar charts. They also identified that shorter bars increase comparison difficulty.

Panavas et al. [19] also built upon the research conducted by Cleveland & McGill [5] by adapting it for children, specifically, by designing and conducting experiments to understand the graphical perception of children. They found that graphical perceptions between children and adults were similar; however, children were more inaccurate in their visual decoding judgments.



(a) Separated Bars (b) Adjacent Bars (c) Aligned Stacked Bars (d) Unaligned Stacked Bars (e) Divided Bar

Figure 2: Overview of the types of bar charts used in our study, adapted from previous research [23].

All aforementioned works have focused on the graphical perception of only sighted users, the graphical perception of low-vision users is still an unexplored research topic. While low-vision users do often have some residual vision, the need for magnification and their visual acuity introduce variables, thereby making it less likely that the prior findings with sighted users are applicable to low-vision users. This paper therefore addresses this knowledge gap by examining the graphical perception of low-vision users.

3 METHODOLOGY

3.1 Participants

We recruited 25 low-vision participants (12 females and 13 males) via email lists and word-of-mouth. Among the volunteers who signed up, we randomly selected 13 males and 12 females, choosing more males because a higher number of males had signed up for the study. Note that all volunteers identified their gender as either male or female. The participants had an average age of 23.8 years (Median = 24, Minimum = 17, Maximum = 37). The inclusion criteria were: (i) proficiency in screen magnifiers; and (ii) familiarity with bar charts. Demographic details are provided in Table 1.

3.2 Apparatus

User Interface. To understand low-vision users' perception of bar charts, we built a custom web application (Figure 4) that was presented to the participants on a Dell monitor (dimensions were 1440 x 1024 pixels). A demo video providing a detailed overview of this application is available on GitHub[1]. The participants interacted with different types of bar charts on this web application using a custom-built screen magnifier. The magnifier features were designed to replicate the functionality of the participants' preferred screen magnifier tool, ZoomText, thereby eliminating the need for them to learn new interfaces and thus allowing them to focus on their core tasks. The custom magnifier's purpose was to capture and log all instances of zooming and panning on the user interface without adding extra learning overhead for the participants. If the participants zoom in or out of the chart, the chart on the user interface undergoes either magnification or minification, respectively, thereby automatically changing the dimensions of the original chart by a scale factor. The application recorded these changes in the dimensions of the chart. The implementation details of the magnifier are also available on GitHub[1]. All user activity data was logged and stored in CSV format for subsequent analysis (Figure 4 (6)).

[1]https://github.com/accessodu/LV_Graph_BarCharts.git

3.3 Design

In a within-subject experiment, participants performed representative tasks on different bar charts. Influenced by prior work for sighted users [23], the selected perception-based task was: "Determine the percentage coverage of the shorter annotated bar relative to the longer annotated bar". We chose the following types of charts (Figure 2) for the study:

- Simple bar charts – the charts were manually constructed, where the differences between the annotated bars were either 26.1%, 46.4%, 56.2%, 68.2%, or 82.5%, following recommendations from prior research [23]. The separation between bars ranged randomly from 125 to 300 pixels. To mitigate confounding factors, the taller bar was always positioned on the left side of the interface to provide a consistent reference point and avoid biases due to varying bar positions. This ensured that all comparisons were based on the visual characteristics of the bars rather than their screen locations.
- Stacked bar charts – both aligned and unaligned bars arranged in two separate columns and divided bars within a single column.

Additionally, distractor bars were placed between the two annotated bars. There were two types of distractors: short distractors, which were significantly shorter than the task bars, and long distractors, which were tall enough to visually obstruct the comparison between the task bars. The heights of the distractors were predetermined and fixed to avoid any possible confounding effects. In our research, we used the same experimental setup, including the charts provided by Talbot et al. [23] (see Figure 2).

3.4 Procedure

The experimenter first obtained the participant's formal consent before briefly explaining the study's goals. The experimenter then introduced the user interface to the participant and conducted a practice session of about 20 minutes to help the participant get comfortable using the custom magnifier on the user interface. After the practice session, the experimenter asked the participant to complete the study tasks in a predetermined counterbalanced order. We set one constraint, i.e., users were instructed to provide their responses in less than 15 seconds, extending the 7-9 second limit used in prior research for sighted people [23]. This extension accounted for the screen magnification-based panning overhead and was also based on average practice session times. The time constraint served two purposes: first, to focus on graphical perception by emphasizing quick judgments, ensuring participants relied on immediate visual perception rather than extended cognitive processes; and second, to standardize task conditions for all participants by avoiding confounding effect of varying task duration. Users were allowed to adjust their seating positions from the screen. Users were then shown the web application and were asked to state their answer for the task anywhere in the bandwidth of 0% to 100% after comparing annotated bars (black dot as seen in Figure 2). In addition, we used the think-aloud protocol [4] and conducted an exit interview with participants (see Table 2) to gain insights into their cognitive strategies while doing the tasks.

3.5 Data Analysis

We eliminated any outlier data points to avoid disparity in our statistical analysis. These outliers included participants randomly guessing after giving up because of the mental strain of going over multiple charts and a few participants also gave up and started giving random answers. To determine outliers, we compared the accuracy of user responses against the ground truth and calculated Pearson's R correlation [17]. We included data points with a correlation greater than 0.7 in our study while excluding those with values less than 0.7.

4 RESULTS

We quantified the discrepancy between the actual ground-truth values and the participants' estimations by using the log (base 10) of the absolute error between them. The log of the absolute error provides clearer insights into the proportional differences between perceived and actual values. It emphasizes relative errors rather than absolute quantities, which is useful in understanding the impact of errors in a context where percentages or proportional differences are more meaningful than absolute differences.

4.1 Evaluation

(i) Standard Bar Charts: The majority (90%) of participants in our study expressed a preference for viewing both bars of comparison within the same viewport (percentage was determined from qualitative data). We observed that the separation between the bars and the presence of distractors increased the error rate during quantitative comparisons of the bars. Specifically, when the bars were separated, the log absolute error averaged 0.87 (Median: 0.91, Max: 1.03, Min: 0.61). In contrast, adjacent bars demonstrated a lower incidence of error with an average of 0.65 (Median: 0.63, Max: 0.79, Min: 0.43) as shown in Figure 3(a). Further analysis concerning the impact of distractors revealed that short distractors typically had a minimal impact, with an average log absolute error of 0.78 (Median: 0.76, Max: 0.97, Min: 0.66). However, tall distractors significantly increased errors in both adjacent and separated bar comparisons, with an average log absolute error of 0.96 (Median: 0.97, Max: 1.03, Min: 0.82) (see Figure 3(c)).

Analysis showed that separated bars accompanied by tall distractors had a higher average mean error of 0.95 (Median: 0.84, Max: 1.16, Min: 0.77) compared to adjacent bars with the same distractors, which averaged an error of 0.72 (Median: 0.80, Max: 0.96, Min: 0.45), $\chi^2 = 8.1, p < 0.001$. For twelve participants however, we observed an opposite trend: adjacent bars with tall distractors yielded a more pronounced error, averaging 0.89 (Median: 0.92, Max: 1.01, Min: 0.77), while separated bars with tall distractors had a lower average error of 0.73 (Median: 0.82, Max: 0.97, Min: 0.54).

(ii) Multi-Column Stacked Bar Charts: Low-vision users generally found stacked bars more challenging to interpret compared to simple bar charts, with 60% of participants indicating heightened cognitive burden. The mean log absolute error for stacked bar graphs was 0.83 (Median: 0.78, Max: 1.05, Min: 0.64), compared to a mean error of 0.74 for unstacked bars (Median: 0.73, Max: 0.89, Min: 0.62) ($\chi^2 = 9.3, p < 0.001$) (see Figure 3(b)). We also observed that the average log absolute error for comparing aligned bars (Figure 2(c)) was 0.64 (Median: 0.61, Max: 0.66, Min: 0.57), which was lesser than the error for unaligned bars (avg: 0.77, Median: 0.74, Max: 0.98, Min: 0.44) (Figure 2(d)). This finding highlights the substantial impact of bar alignment on the accuracy of interpreting stacked bars.

(iii) Single-Column Stacked Bar Charts: We also studied stacked bars in a single column, i.e., divided bars (see Figure 2(e)). These charts exhibited the highest degree of error among the bar chart variants examined, aligning with the observations of Talbot et al. [23]. The log absolute error for divided bars averaged 0.91 (Median: 1.07, Max: 1.32, Min: 0.88). However, we observed that the presence of intervening bars and the separation between bars significantly affected the perception of single-column stacked bar charts among low-vision participants, with distractors contributing approximately an additional 0.3 points of error. Notably, the error rate for adjacent bars was slightly higher (by 0.55 points) than for separated bars.

4.2 Analyses

Deeper analyses of the collected study data revealed numerous reasons underlying the above reported participants' performance. We observed that these reasons belonged to diverse categories: accessibility issues, usability/UX issues, and perception-related issues. In this section, we mainly focus on the perception-related issues, however, we also describe how other issues influenced low-vision perception wherever appropriate.

(i) Separation effect: Talbot et al. [23] noted that sighted individuals face greater difficulty when comparing bars that are spaced apart in bar charts, regardless of the presence of distractors, a phenomenon known as the 'Separation Effect.' In our study, we noted a similar trend among low-vision participants for separated and adjacent bars in bar charts *without distractors*. The need for zooming and panning, a known UX issue, contributed to this trend. The process of panning back and forth – first to approximate the height of the taller bar, then pan to the shorter bar, and finally to pan back again for confirmation, introduced confusion, resulting in higher error rates in separated charts without distractors.

However, in charts *with distractors*, low-vision users typically viewed both annotated bars in separated bar charts within a single viewport to avoid panning because, with panning, it was difficult for participants to identify the task-specified bars amidst all the

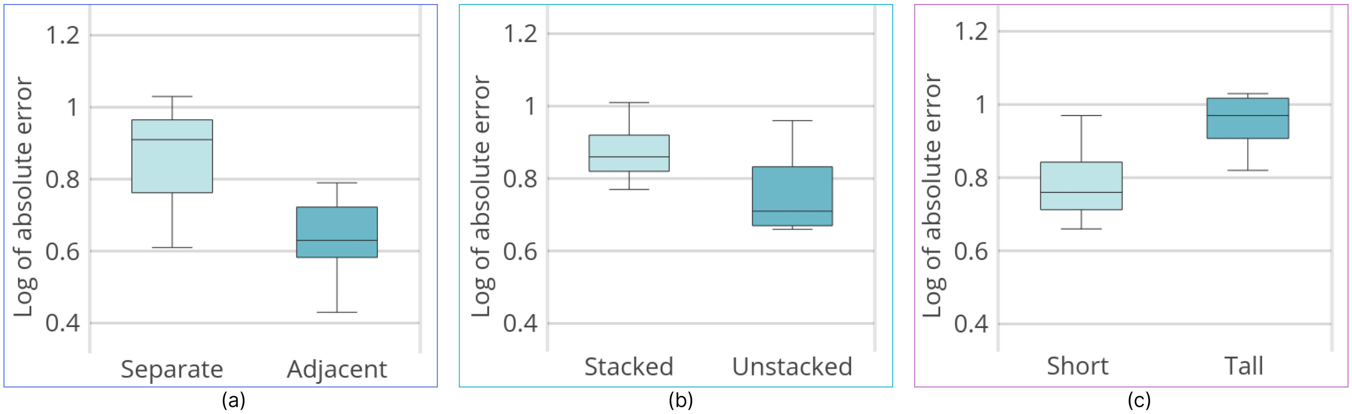


Figure 3: Box plots showing the difference in error estimations for (a) Separated vs. adjacent bars, (b) Stacked vs. unstacked bars, and (c) Short vs. tall distractor bars

visual clutter in the chart. However, this strategy often resulted in increased blurring, leading to greater approximation errors. Furthermore, the presence of distractors led to higher error approximations in adjacent bar comparisons compared to separated bar comparisons for some participants, indicating a strong influence of distractors which is discussed next.

(ii) Influence of distractors: Talbot et al. [23] noted in their research that it was unclear from the initial data whether distractors affected the difficulty of comparing separated bars versus adjacent bars in bar charts. However, further analysis of their data revealed that tall distractors increased the difficulty for both types of comparisons (i.e., separated and adjacent bar comparison), and separated bars with tall distractors were more difficult to compare than adjacent bars with tall distractors. They also emphasized the need for additional research to clarify the mechanisms through which tall distractors disrupt the height comparison task.

Our findings showed similar results across the majority of the participants; however, we did observe contrasting results with 12 participants for whom approximation errors were higher for adjacent bars with tall distractors compared to those for separated bars with tall distractors. Our observations showed that this contrast occurred because of vision blur [28], as the presence of tall distractors causes more blurring, as seen in Figure 1; this caused the participants to estimate incorrect percentages as they could not correctly judge the height of the smaller adjacent bar and they always showed a tendency to overestimate the height of the smaller adjacent bar.

We observed that low-vision users' visual attention naturally tend to focus on striking features of a bar chart, for example, tall bars in a bar chart. When faced with two tall bars among shorter distractors, users instinctively concentrate on the taller bars, allowing the shorter ones to perceptually recede into the background, rendering errors associated with short distractors insignificant.

(iii) Blurring effect: During the think-aloud process, 80% of the participants pointed out the height of annotated bars on the web application, often either overestimating or underestimating their heights, particularly in charts with distractors. This discrepancy is attributed to a "blurring effect" experienced by low-vision users, where a bar perceived as 50px in height by a person with normal sight might be estimated by someone with a visual impairment to be within a range of 40px to 60px, depending on their visual acuity, due to a blur that causes the top of the bar to smudge as shown in Figure 1(b). Another known UX issue is that low-vision users would need to magnify and analyze each bar individually before making a comparison to mitigate this "blurring effect" as shown in Figure 1(c), as this effect can lead to an increased error rate in the interpretation of charts. However, further investigation must be conducted to confirm this and to better understand how various visual aids or adaptive technologies, such as screen magnifiers, can minimize such perceptual discrepancies.

(iv) Unalignment effect: The findings regarding unaligned bars in stacked charts are consistent with those observed by Talbot et al. [23], who noticed an 'unalignment effect' where unaligned bars resulted in higher errors compared to aligned bars. Additionally, Cleveland & McGill [5] noted that it was more challenging to make height comparisons between unaligned bars than between bars aligned to a common baseline, suggesting that position comparison is a fundamentally easier visual task than length comparison.

Among our low-vision participants, the higher error rates in unaligned bar graphs could be attributed to the 'Parallel Line Illusion' (PLI), where the perceived length of a target line is influenced by a contextual line positioned parallel to it [32]. The PLI distorts perceived length such that a target line positioned adjacent to a long contextual line appears shorter than its actual length, while if it is next to a short contextual line, the target line is overestimated and appears longer. This phenomenon underscores the role of length contrast in human perception and illustrates how visual context can significantly affect accuracy in graphical interpretations, especially for individuals with visual impairments.

Additionally, stacked bar charts in our study featured at most two columns with four bars stacked as distractors (see Figure 2). Participants employed a straightforward vertical panning strategy and utilized maximum zoom to perform the task. However, in the presence of distractors, participants struggled to discern the horizontal differentiation lines, often perceiving adjacent stacked bars as a single unit, thus significantly increasing error rates.

Note that the swiftness of the participants' responses might have also impacted their perceptual accuracy. It is possible that their ocular system had not fully adjusted to the display – a phenomenon known as the accommodation reflex – causing them to make judgments before their visual adaptation was complete [9].

5 DISCUSSION

Our study uncovered several key insights: (i) Low-vision users often overestimate or underestimate the height of bars in a bar chart due to 'blurring effect' that can cause smudges on top of bars ; (ii) Low vision users do not perceive charts well in the presence of tall distractors as they are unable to effectively leverage their screen magnifiers; (iii) Unaligned bars result in higher error rates due to the 'Parallel Line Illusion Effect'; (iv) Adjacent bars in stacked charts are harder to perceive than non-adjacent bars. Our study also was limited in certain aspects, which paves the way for for future research on this topic.

One limitation was that in the study task, the dot's placement on the bar was not centered but shifted towards its lower end, which may have influenced how participants identified the bars. Also, there was no provision for participants to adjust contrast and color settings on the charts, requiring them to interact with the charts in their default state. Recruiting a diverse group of low-vision participants also posed a challenge, and a broader range of visual acuity levels might have offered a deeper understanding of accuracy variations across these levels. Additionally, the study did not consider the participants' visual field measurements.

Relying solely on participants' think-aloud and exit-interview feedback for analyses is another limitation of our work. A deeper analysis is possible by adapting methods involving eye-tracking [26], which can potentially uncover fine-grained gaze behaviors of low-vision individuals during graph perception tasks. In future studies, we aim to expand our work using gaze-based metrics to formulate better bar chart design guidelines for low vision users.

Lastly, drawing from prior research that compares the graphical perception of adults and children [19], we recognize the importance of expanding our studies to include a diverse set of visual encodings in future, which can potentially inform the design of usable data visualizations for low-vision individuals.

Low-vision individuals often find data charts overwhelming, particularly when using screen magnifiers, because of increased perceptual effort due to magnification and panning [24]. The perceptual effort, which refers to the cognitive load involved in interpreting visual information from charts, has been studied extensively for sighted users [7] but not adequately quantified for low-vision users. We recognize the importance of quantifying perceptual effort for low-vision users to enable the creation of more accessible and efficient data charts.

Our research uncovered that unlike sighted users, where distractors on bar charts typically have minimal impact, these elements profoundly affect low-vision users. This finding highlights the necessity for developing an intelligent screen magnifier with an auto-panning algorithm tailored for chart interaction. This technology would utilize data saliency—key areas of a chart that draw more attention, such as axis labels and bar tops, which can be obtained from the logged data CSV from our custom screen magnifier (see Section 3.2). By automating panning to these high-priority areas, such a tool could enhance the chart-reading experience for low-vision users.

6 CONCLUSION

As the prevalence and variety of data visualizations on web platforms grow, it becomes imperative to confront challenges that arise due to accessibility and usability of these visualizations, especially for low-vision individuals. In this research, we conducted experiments to identify low-vision graphical perception on bar charts. Our results indicate that while low-vision individuals process chart information similarly to sighted users, their need for magnification coupled with varying visual acuity, introduce variables that make it difficult for them to make precise visual judgments. Our future studies aim to delve deeper into the perceptual effort and cognitive strategies low-vision users employ in comparing bar heights to further understand low-vision usability of bar charts. Based on our findings, we plan to develop an intelligent screen magnifier with automatic panning to reduce cognitive overload for low-vision users. Additionally, we will employ eye-tracking to obtain deeper insights into the viewing patterns of low-vision users. Overall, gaining a thorough, experimentally-supported understanding of basic graphical perception abilities of low-vision individuals, represents a significant and promising step forward in HCI for enhancing accessible visualization practices.

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A STUDY APPLICATION

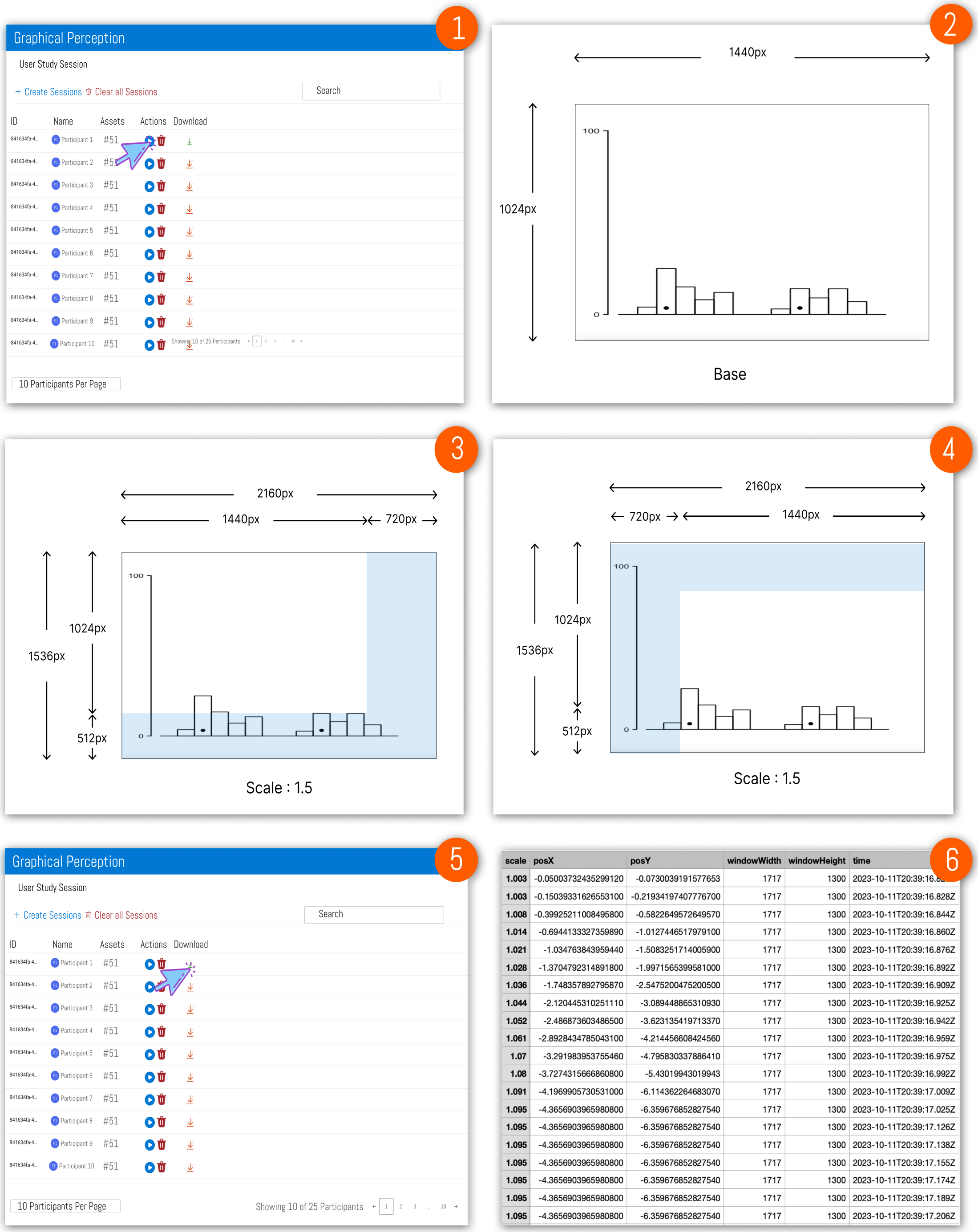

Figure 4: Screenshots of the User Interface used in the study. (1) Study setup sessions; (2) Sample graph; (3) Magnified chart view; (4) Magnifier panning; (5) Session log data; and (6) Saved CSV data.

B EVALUATION USER STUDY PARTICIPANT DEMOGRAPHICS

Table 1: Participant demographics. All information was self-reported (Note: N/A indicates that the participants were not sure of their medical condition).

ID	Age/ Gender	Diagnosis	Visual Acuity		Daily Web Browsing	Assistive Technology
			Left Eye	Right Eye		
P1	21/M	Optic atrophy	20/100	20/200	5 hours	Screen magnifier
P2	17/M	Glaucoma	20/100	20/200	5 hours	Screen magnifier
P3	18/M	N/A	20/200	20/400	5 hours	Screen magnifier
P4	26/F	N/A	20/100	20/200	7 hours	Screen magnifier, screen reader
P5	18/M	Leber congenital amaurosis	20/400	20/600	5 hours	Screen magnifier
P6	24/M	Optic atrophy	20/200	20/400	7 hours	Screen magnifier
P7	19/F	Leber congenital amaurosis	20/200	20/400	5 hours	Screen magnifier
P8	30/F	Albinism, nystagmus	20/400	0	5 hours	Screen magnifier
P9	25/F	Cataracts	20/100	20/100	5 hours	Screen magnifier
P10	19/F	Glaucoma	20/100	20/200	7 hours	Screen magnifier
P11	37/M	Retinitis pigmentosa	20/500	0	5 hours	Screen magnifier
P12	22/M	Glaucoma	20/400	0	5 hours	Screen magnifier
P13	23/M	Leber congenital amaurosis	20/400	20/200	5 hours	Screen magnifier
P14	17/M	Cataracts	0	20/500	4 hours	Screen magnifier
P15	33/F	N/A	20/200	20/400	4 hours	Screen magnifier
P16	27/M	Albinism, nystagmus	20/200	20/400	5 hours	Screen magnifier
P17	21/F	Stevens-Johnson syndrome	20/200	20/400	5 hours	Screen magnifier
P18	18/F	N/A	20/100	20/200	7 hours	Screen magnifier
P19	24/F	N/A	20/500	0	5 hours	Screen magnifier, screen reader
P20	28/M	N/A	0	20/400	5 hours	Screen magnifier
P21	20/F	Cataracts	20/100	20/200	5 hours	Screen magnifier, screen reader
P22	29/M	Cataracts	20/400	0	5 hours	Screen magnifier, screen reader
P23	25/F	Glaucoma	20/500	0	3 hours	Screen magnifier
P24	25/M	N/A	0	20/500	4 hours	Screen magnifier, screen reader
P25	29/F	Optic atrophy	20/500	0	5 hours	Screen magnifier, screen reader

C EXIT INTERVIEW

Table 2: Paraphrased Questions for Low-Vision Participants

Question	Paraphrased Question (LOW_VISION)
Theme1.	I want to know something about your demographics 1. Gender 2. Age 3. Education Level 4. Eye problem/diagnosis 5. Preference screen reader/magnifier
Theme2.	Think about a recent bar graph you have come across on your phone or computer 6. Within how long ago did you see it? 7. How often do you come across bar graphs in your daily activities, such as in reading materials, online content, or workplace documents? 8. What did you do when you encountered the graph?
Theme3.	I will ask some Habit Questions 9. Are there particular presentations of graphs that you find more intuitive or easier to understand, and how often are graphs available in such formats? 10. Is comprehending/understanding bar graphs easy or difficult? 11. What do you do if the bar graph is hard to comprehend/understand? 12. Can you describe the usual challenges you face when interpreting bar graphs due to low vision? 13. What strategies or adaptations have you developed to understand bar-based graphical information effectively?
Theme4.	One last Closing Question: 14. Are there any additional insights, preferences, or experiences you would like to share regarding your interaction with graphs?