

Usability and accessibility of selected e-commerce services

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Abstract

The development of e-commerce necessitates websites that are usable and accessible for all. The aim of the study was to evaluate the usability and accessibility of six e-commerce platforms (desktop and mobile versions) using eye tracking and the SUS questionnaire with 15 participants. Automated accessibility assessments, while useful, did not consistently correlate with users' subjective opinions. Eye-tracking data confirmed a strong relationship between interface elements and usability. Statistical analysis confirmed the hypothesis regarding a consistent user experience across all versions. Although automated tools provided valuable technical data, they did not fully reflect actual user behavior.

Keywords: usability; accessibility; e-commerce services; eye tracking; SUS; WCAG

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1. Introduction

E-commerce has changed the way businesses interact with their customers, becoming the foundation of the modern digital economy. With the growth of online shopping, the usability and accessibility of e-commerce platforms appear to be decisive factors in user satisfaction and commercial success. A high-quality user experience directly impacts customer loyalty, conversion rates, and overall business performance.

Despite significant technological advances and the development of web design standards, many e-commerce platforms exhibit significant usability barriers that hinder the user experience. These include complex navigation structures, inefficient order fulfillment processes, and a lack of features that support accessibility for users with disabilities. These challenges are particularly evident among diverse user groups, including older adults and people with various types of disabilities [1].

Recent research shows that systematic usability evaluation using established methods can significantly improve platform functionality [2]. Various approaches to evaluation have been proposed, ranging from heuristic-based expert reviews to comprehensive user testing protocols to automated accessibility checking tools [3].

International standards such as WCAG (Web Content Accessibility Guidelines) [4] provide a framework for assessing accessibility. However, studies show that many platforms do not meet basic accessibility requirements. This creates significant barriers for millions of users with disabilities who depend on assistive technologies to access online services. Thus, the main motivation of this study is to conduct a comprehensive, multi-method assessment of selected e-commerce platforms using a variety of evaluation methods. Moreover, in the study common barriers in terms of usability and accessibility, as well as compliance with applicable standards are identified.

The following research hypotheses are defined:

H1. E-commerce platforms that show accessibility problems, identified using automated tools, also receive lower ratings from users.

H2. The level of usability and accessibility is comparable in both the mobile and desktop versions of websites.

2. Related works

The selection of literature for this study was dictated by the need to establish a theoretical and methodological basis for assessing the usability and accessibility of e-commerce. The work of Huang and Li presents a comprehensive system for evaluating the usability of C2C (Consumer to Consumer) e-commerce websites, combining various research methods [5]. The work was selected for its approach to usability evaluation, playing a fundamental role in the methodology as a foundation for proposing an integrated evaluation system adapted to various e-commerce platforms.

The basis for accessibility was established based on the work of Patvardhan and Rande on website accessibility in the context of e-commerce, with an emphasis on social integration and sustainable development [4]. In addition, a detailed analysis of e-commerce accessibility for people with disabilities was conducted by Sohaib and Kang using WCAG automated accessibility tools [1]. These studies provide both a theoretical basis and a practical approach to accessibility testing. A comprehensive review of guidelines for use in e-commerce [6] was selected as the primary source of best practices and industry standards, while a practical study by Jain and Purandare [7] on usability testing methods provides detailed testing procedures for the empirical part of this research.

The customer experience perspective is addressed through the quality assessment presented in Radziszewska's article, which combines technical aspects with user perception [8]. The methodological diversity index is enhanced by the innovative combination of heuristic evaluation and eye tracking developed in the article by Duwers and Dzieńkowski [9]. Considerations regarding accessibility are expanded by a comprehensive evaluation conducted by Gonçalves, Rocha, Martins, and Branco, which includes blind users, providing valuable data on the actual barriers encountered when shopping online [2].

Cross-cultural perspectives are introduced through an evaluation of Pakistani e-commerce portals by Rahman et al., who combined Nielsen's heuristics with WCAG tests [10]. In addition, Zheng's comparative analysis between China and Thailand [3] complements this. Wang's user interface study provides important guidelines for intuitive interface design [11]. In turn, Immanuel and Thoyyibah's innovative approach combining SUMI (Software Usability Measurement Inventory) methods with the TAM (Technology Acceptance Model) offers insights into the factors influencing technology adoption by users [12].

Methodological synthesis is demonstrated by Wahyuningrum's combination of heuristic evaluation with SUS (System Usability Scale), showing the synergy between evaluation techniques [13]. Local market conditions are analyzed in Gąsiorkiewicz's work through the analysis of Polish B2C websites using the V-U-A (Visibility-Usability-Accessibility) methodology [14]. An article by Butnampetch presents research on the checkout process, which shows how insight into specific processes is critical to conversion optimization [15].

Methodological rigor is reinforced by a review by Silva and colleagues on user-centered evaluation procedures [16]. This methodology provides a systematic analysis of research methods and identifies gaps in current practices. Sohaib's article deals with the evaluation of contemporary cloud-based solutions using the Fuzzy TOPSIS methodology [17]. Lewis and Saur's 2018 study expands the methodology for comparing results by analyzing the components of the SUS scale based on the overall score and interpretive norms, which confirms the statistical significance of the model [18]. To confirm the reliability of the interpreted results, Malapane and Ndlovu conducted an analysis of the internal consistency of the measurement tools. Such an analysis is an essential element of the methodological verification process [19]. We also selected the study by Vigo and colleagues, which includes an accessibility metric calculated based on assessment tool reports, enabling the monitoring of changes in access levels [20].

Each selected article contributes to a comprehensive understanding of usability and accessibility in e-commerce, forming the theoretical and methodological basis for this research.

3. Material and Methods

The study uses a mixed-method approach combining quantitative and qualitative assessment methods to provide a comprehensive analysis of the usability and accessibility of selected e-commerce platforms. This methodology integrates automated accessibility tools (WCAG), eye tracking, and the SUS questionnaire, enabling detailed results to be obtained, taking into account the complexity of evaluating user experiences.

3.1. Data object

The study included six leading e-commerce websites representing different product categories: Allegro (the largest Polish trading platform), Amazon (a universal sales

platform), eBay (global trading platform), Empik (culture and lifestyle), x-kom (electronics), Zalando (fashion and footwear). These websites were selected due to their high position in popularity rankings and their availability in desktop and mobile versions.

A detailed analysis of each website covered four e-commerce subpages: the home page, the product category page, the product card, and the shopping cart with the order summary. These subpages were selected due to their key importance in the user conversion path and frequent problems with accessibility and usability.

3.2. Participants

The research group consisted of 15 students from the Faculty of Computer Science at the Lublin University of Technology. The participants were first- and second-year students, selected for their experience in online shopping and good knowledge of computers and mobile devices. This group was deliberately selected to ensure homogeneity in terms of e-commerce experience. Due to the use of eye tracking in further research, participants had to have normal vision. Table 1 presents information about the age of the study participants.

Table 1: Data on the age of the study group

Partici- pants (n)	Age range (years)	Aver- age (years)	Standard de- viation (years)
15	20-25	22.40	1.92

3.3. Eye-tracking study

The study was conducted at a testing station located in the laboratory room of the Department of Computer Science at the Lublin University of Technology, which provided optimal lighting conditions. Eye movements were recorded using a Gazepoint GP3 HD device with iMotions software version 10.1. Before the study began, participants had to sit at an appropriate distance from the eye tracker in order to calibrate the device.

To ensure high data quality, each participant underwent a nine-point calibration to ensure accurate eye tracking. The acceptance criteria required a "Good" or "Excellent" rating, which guaranteed the accuracy of the eye movement reading. After successful calibration, participants performed two tests, which consisted of finding specific elements on the website. The tasks were designed to replicate typical e-commerce user behavior. Two studies were conducted to better understand user behavior during online shopping. Study A examined the ease of finding specific information on e-commerce websites, following the scenario presented in Table 2. Study B focused on activities related to completing a purchase, and its scenario is shown in Table 3. Both studies were conducted on selected e-commerce platforms, taking into account both desktop and mobile versions. The aim of the studies was to replicate the online shopping process, regardless of the device the user typically uses.

Table 2: Research scenario for study A

No.	Task content
1	Locate the search box on the home page.
2	Locate the product filter section.
3	Locate the price filter.
4	Locate the option to sort results.
5	Locate the product price on the product card.
6	Repeat the procedure (steps 1-5) for the five remaining e-commerce websites.
7	Repeat the procedure (steps 1-6) for the mobile view.

Table 3: Research scenario for study B

No.	Task content
1	Locate the product category menu on the home page.
2	Locate the option to sort products by price.
3	Locate the button to add a product to the shopping cart.
4	Locate the shopping cart icon.
5	Locate the button to change the quantity of a product in the shopping cart.
6	Locate the button for removing a product from the shopping cart.
7	Repeat the procedure (steps 1-5) for the five remaining e-commerce websites.
8	Repeat the procedure (steps 1-6) for the mobile view.

To ensure data consistency, all participants performed the same tasks in a specific order. Before viewing the website screenshot, the participant read the instructions for the element to be located. After confirming the instructions, they began searching for the element on the displayed page. A maximum of six seconds was allowed to locate the element.

3.4. Survey research

A standardized SUS questionnaire [13] was used for subjective assessment of website usability. The questionnaire consists of ten questions, which are alternately positive and negative statements. All questions in the questionnaire are presented in Table 4.

Table 4: SUS questionnaire

No.	Statement
1	I think I would like to use this website often.
2	I think the website is unnecessarily complicated.
3	I think the website is easy to use.
4	I think I would need technical assistance to use this service.
5	I think the various functions of this service are well integrated.
6	I think there are too many inconsistencies in this service.
7	I imagine that most people would learn how to use this service very quickly.

- 8 I find this website very difficult to use.
- 9 I feel very confident using this website.
- 10 I would have to learn a lot before I could use this website freely.

The answers to the questions were evaluated using the Likert scale [19]. The Likert scale is a five-point scale expressing the degree of agreement. The Likert scale is presented in Table 5.

Table 5: Likert scale [19]

No.	Statement
1	Strongly disagree
2	Somewhat disagree
3	No opinion
4	Somewhat agree
5	Strongly agree

The respondents completed the questionnaire immediately after completing the eye-tracking study to ensure that their experience with each service was fresh in their minds. The questionnaire was available in paper and digital versions, separately for the mobile and desktop versions.

The next stage of the analysis was to calculate the SUS score. The score can be presented using formula (1) [13]:

$$SUS = \left[\sum_{n=1}^5 (x_{2n-1} - 1) + (5 - x_{2n}) \right] \times 2.5 \quad (1)$$

where x_n is the respondent's answer to question n . The SUS score ranges from 0 to 100 points. The higher the score, the better the usability rating of the website. The CGS (Sauro–Lewis Curved Grading Scale) [18], presented in Table 6, was used to evaluate the results.

Table 6: Sauro–Lewis Curved Grading Scale

Rating	SUS Score range	Percentile range
A+	84.1-100	96-100
A	80.8-84.0	90-95
A-	78.9-80.7	85-89
B+	77.2-78.8	80-84
B	74.1-77.1	70-79
B-	72.6-74.0	65-69
C+	71.1-72.5	60-64
C	65.0-71.0	41-59
C-	62.7-64.9	35-40
D	51.7-62.6	15-34
F	0-51.6	0-14

3.5. Accessibility testing

In order to verify the compliance of e-commerce websites with WCAG guidelines, automatic verification was performed using the following tools: axe DevTools, Light-house, Siteimprove Accessibility Checker, and WAVE.

The use of these tools allows for systematic and effective identification of technical barriers for all tested websites.

Axe DevTools, developed by Deque Systems, is a tool for assessing the compliance of websites with WCAG 2.1 (level AA) guidelines [21]. The tool automatically detects problems such as the lack of alternative text for images and insufficient contrast ratio. The test was conducted using version v4.117.0. The website was evaluated by summing up errors marked as “Critical” and “Serious.”

Google's Lighthouse is an integrated tool in the Chrome browser for auditing websites. In order to assess accessibility, Lighthouse was run in Accessibility mode only, which allowed for the identification of issues related to WCAG guidelines. The tool automatically generates a report, indicating elements that need improvement and presenting an overall accessibility score on a scale from 0 to 100.

Siteimprove Accessibility Checker from Siteimprove is a tool for automatically checking website accessibility. It helps identify issues related to WCAG [22]. The result of the accessibility analysis is the number of issues displayed and their division into three levels: A/AA/AAA. Version 2.0 was used to conduct the study. The number of errors on the website affected the usability rating of the website.

WAVE is a free online tool created by WebAIM for automatic analysis of website accessibility [23]. WAVE analyzes the content of a website, identifying interface elements that may pose obstacles for people with disabilities. Version 3.3.0.1 was used in the study. The generated report classifies errors into the following categories: “Errors,” “Contrast Errors,” and “Alerts.” The sum of ‘Errors’ and “Contrast Errors” was used to evaluate the website.

To ensure consistency of results, the tests were conducted at the same time and using the same browser. The study covered selected e-commerce websites and their subpages. The desktop view was analyzed at a resolution of 1920x1080px, and the mobile view at 414x896px. The mobile view was simulated using the Chrome browser's developer tools.

The collected results were normalized, taking into account differences in the rating scale. Based on the normalized data, an overall accessibility index will be calculated for each analyzed website, separately for the desktop and mobile versions. The formula for calculating the normalized accessibility index is presented in (2) [20]:

$$D = 100 - \frac{E}{E_{max}} \times 100 \quad (2)$$

where E is the number of errors detected for a given website, and E_{max} is the maximum number of errors in the set. The final accessibility index was determined as the arithmetic mean of the results obtained from the automatic tools, for both the mobile and desktop versions.

3.6. Metrics

In order to comprehensively assess the accessibility and usability of the websites under review, the following metrics were used:

- **Eye-tracking metrics:** The primary metric analyzed in this study was TTFF (Time To First Fixation), measured in milliseconds. TTFF is defined as the time from the moment a webpage was presented until the participant first locates the specified element with their gaze. Lower TTFF values indicate that users locate elements more quickly [24]. Other key metrics include both the number of fixations and the duration of individual fixations. The number of fixations indicates how many times the participant shifted their gaze across the page to process information. A higher value suggests greater difficulty in navigating the interface [2]. Fixation duration measures how long the eye remains stationary on a single point. The measured values were collected and averaged for each website and its respective version.
- **SUS questionnaire metrics:** The SUS score was calculated and averaged on a scale of 0 to 100 for each website, separately for the mobile and desktop versions.
- **Accessibility metrics:** The accessibility score on a scale of 0 to 100 was calculated as the arithmetic mean of the tools used for each website, separately for the mobile and desktop versions.

For each metric, the mean, variance, standard deviation, and confidence interval were calculated. Differences between versions were compared using Student's t-test. The effect size was assessed using Cohen's d coefficient, and the significance level was set at $\alpha = 0.05$.

4. Results

4.1. Eye-tracking results

4.1.1. Time To First Fixation (TTFF)

The experiment was designed and conducted using the iMotions platform, which enables generating visualizations such as heatmaps and scan paths, defining Areas of Interest (AOIs), and calculating indicators. iMotions software was used to read the TTFF indicator, which allows for easy and effective data analysis after the study. In order to correctly calculate the TTFF, the AOI editor was used to draw the areas of the interface elements that the subjects had to locate. After defining the areas of interest, the software generated heat maps showing the areas of greatest interest to the subjects. Figure 1 shows the heat map for the Allegro website.



Figure 1: Study results in the form of a heat map

Eye-tracking paths are used to analyze the trajectory of the gaze, documenting the sequence of the subject's eye movements. This makes it possible to analyze in detail how the subject viewed the website. Figure 2 shows the eye-tracking path for the Allegro website.

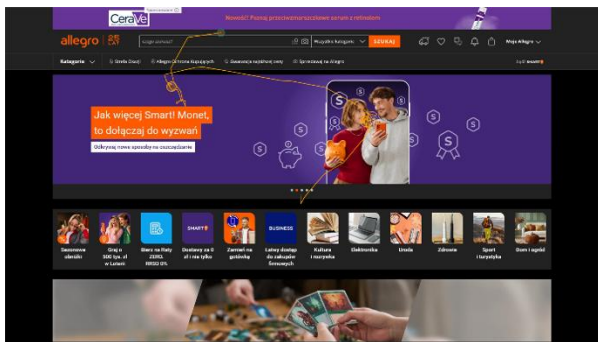


Figure 2: The result of the study in the form of a gazeplot

The file aggregating all data from the eye tracker contains, among other things:

- Study number,
- Participant ID,
- Slide number,
- AOI name,
- All metrics (in milliseconds).

The collected data was averaged for each website. Figure 3 shows a comparison of average TTFF times between views within each website. In order to obtain comparable data, average times were calculated for each website. A lower TTFF value means that the participants found the searched interface element faster.

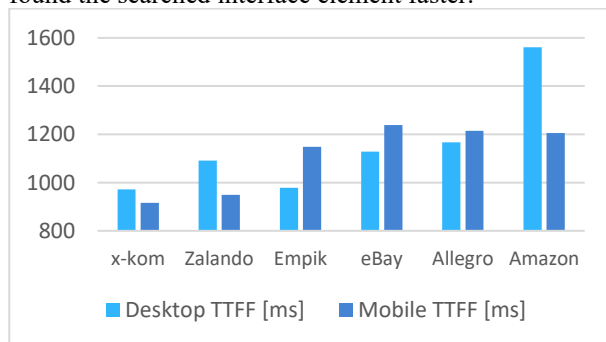


Figure 3: Bar chart comparing the TTFF of two views for all websites

The analysis of the Allegro platform allowed us to determine the average time needed to complete tasks. For each view, the average completion time, variance,

standard deviation, and 95% confidence interval were calculated, allowing for an assessment of the variability of the results. The Student's t-test was used to compare the average times between views, and the effect size was assessed using Cohen's d coefficient. Table 7 presents the Cohen's d effect sizes comparing desktop and mobile views, where 0.2 indicates weak, 0.5 moderate, and 0.8 strong effects.

Table 7: Cohen's d values [25]

Cohen's d value	Effect size
0.2	Weak
0.5	Moderate
0.8	Strong

4.1.2. Fixation Count (FC)

The fixation count indicates how many times the subject's gaze focused on a specific element. A higher fixation count may indicate difficulty in locating the desired element, as well as greater interest in that element. Table 8 shows the average FC for the websites tested.

Table 8: Number of fixations on the websites studied

Website	Desktop	Mobile	Average
Allegro	3.46	3.16	3.31±0.22
Amazon	3.05	2.52	2.79±0.38
eBay	3.52	2.50	3.01±0.72
Empik	2.93	2.91	2.92±0.01
x-kom	3.73	3.08	3.40±0.46
Zalando	3.19	2.55	2.87±0.45

The average number of fixations for the desktop view was approximately 18.9% higher than for the mobile view. The highest number was recorded for the desktop version of the x-kom website, and the lowest for the mobile version of eBay.

4.1.3. Fixation Duration (FD)

Fixation duration indicates the length of a single gaze. Longer fixations mean more time spent absorbing information. The average FD for e-commerce websites is presented in Table 9.

Table 9: Fixation duration for the websites studied

Website	Desktop [ms]	Mobile [ms]	Average [ms]
Allegro	274.79	272.21	273.50±1.82
Amazon	205.79	320.21	263.00±80.90
eBay	193.00	304.31	248.65±78.71
Empik	177.55	229.65	203.60±36.84
x-kom	281.70	260.56	271.13±14.95
Zalando	232.02	213.66	222.84±12.98

The average fixation time for the desktop version was 227.48 ms, and for the mobile version 266.77 ms. The longest time was recorded for the mobile version of Amazon, and the shortest for the desktop version of Empik.

4.2. SUS questionnaire results

The collected responses were analyzed to calculate the overall SUS score for each website. Figure 4 shows the average SUS scores in order from lowest to highest.

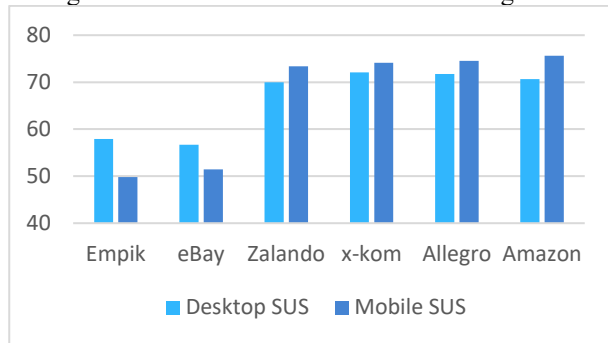


Figure 4: Bar chart comparing SUS scores

The normalized SUS score ranges from 49.83 to 75.6 points. The lowest score was obtained by the mobile version of Empik, and the highest by the mobile version of Amazon.

4.3. Accessibility test results

The results from the automated tools were collected and used to calculate a normalized accessibility coefficient, enabling an objective comparison of the websites. The accessibility results are presented in Table 10.

Table 10: Accessibility results

Website	Desktop	Mobile
Allegro	47.50	54.30
Amazon	51.83	67.12
eBay	80.08	86.80
Empik	15.50	17.20
x-kom	64.05	67.63
Zalando	87.85	87.76

The results range from 15.5 for the desktop version of Empik to 87.85 for the desktop version of Zalando. During automatic testing, some websites prevented the tests from being carried out. In such cases, they were omitted. The accessibility coefficient was calculated only for correctly performed tests.

4.4. Summary of results

In order to verify the research hypotheses, it was necessary to summarize the collected results. Detailed results of the analysis of the difference between the versions are presented in Table 11.

Table 11: Results of the statistical analysis of differences between the desktop and mobile versions

	Accessibility	SUS
Average	60.64	66.51
Standard deviation	24.96	9.60
Pearson	0.35	
Spearman	0.72	
Student's t-test	0.41	
Cohen's d	-0.31	

In order to verify the similar level of usability and accessibility of the websites, a comparative analysis of selected metrics was performed. The results of the TTFF analysis between the views are presented in Table 12.

Table 12: Results of statistical analysis of differences between the desktop and mobile versions

	Desktop	Mobile
Average	1102.56	1123.08
Standard deviation	96.36	112.33
Pearson	0.21	
Spearman	0.36	
Student's t-test	0.62	
Cohen's d	0.20	

The SUS questionnaire provided an objective assessment of the usability of each view. The summary of results for the desktop and mobile versions is presented in Table 13.

Table 13: Results of statistical analysis of differences between the desktop and mobile versions

	Desktop	Mobile
Average	66.52	66.49
Standard deviation	7.17	12.31
Pearson	< 0.001	
Spearman	0.14	
Student's t-test	0.99	
Cohen's d	0.003	

5. Discussion

5.1. Verification of hypothesis H1

The correlation analysis did not reveal a statistically significant relationship between the accessibility test results and the subjective assessment of users. Therefore, hypothesis H1 was rejected.

The calculated Pearson ($r = 0.35$) and Spearman ($r = 0.72$) correlation coefficients presented in Table 11 indicated a weak positive trend, but their p-values exceeded the accepted level of significance [2]. The observed trend may be the result of chance.

Automatic testing tools are not able to reflect the full user experience. They focus on the technical aspect of the website rather than on assessing its usability and ease of navigation. The SUS result may have been influenced by the characteristics of the control group. People familiar with the e-commerce platforms under study do not perceive accessibility issues in the same way as older people or those with visual impairments. Usability assessment involves many factors that cannot be evaluated by automated tests.

An analysis of Table 10 shows that some websites received low accessibility scores for both their mobile and desktop versions. However, as shown in Figure 4, this did not result in negative user ratings. This finding confirms that there is no direct correlation between technical compliance and user experience.

5.2. Verification of hypothesis H2

The analysis of eye-tracking metrics did not reveal any significant differences between the desktop and mobile versions of the tested websites. The average time of the first fixation was very similar, with a difference of 20 ms in favor of the desktop version. The Student's t-test result presented in Table 12 did not show statistical significance with a small effect size. Users located the indicated interface elements in a similar time regardless of the graphic mode of the websites.

The questionnaire results presented in Table 13 indicate an almost identical level of usability. The average score fluctuated around 66 points. The lack of differences is consistent with the eye-tracking results. The participants did not experience significant difficulties related to changing views, which confirms hypothesis H2.

The data on the number of page views in Table 8 further confirms this. The results indicate a comparable level of user engagement across the platforms studied. The data analysis did not reveal any significant differences in user behavior, regardless of which version of the website was displayed.

6. Conclusions

The aim of the study was to assess the usability and accessibility of selected e-commerce websites. A mixed methodology combining automated accessibility analysis, eye-tracking measurements, and the SUS questionnaire was used to verify the hypotheses. The study participants consisted of 15 students from the Faculty of Computer Science who performed shopping scenarios on the tested websites and completed the SUS questionnaire after the eye-tracking session [4].

The results of the study showed no statistically significant correlation between technical accessibility scores (range: 15.5-87.85) and subjective SUS assessments (average score was approximately 66.5 points). Consequently, hypothesis H1 was rejected, indicating that while automated tests proved useful for technical evaluation, they did not accurately reflect actual user experiences [1]. Hypothesis H2 was upheld because the study confirmed the consistency between user experiences (Pearson $r = 0.35$, Cohen's $d = 0.20$) and the alignment of SUS scores with eye-tracking metrics (TTFF: 1102 ms vs 1123 ms).

Key limitations included the small sample size and the demographic homogeneity of the participants, as well as the limited number of websites analyzed. These constraints hinder generalizability, suggesting that future studies should include older adults or individuals with disabilities to better understand accessibility barriers [2]. Furthermore, expanding the pool of sites including thematically related ones presented in a random order would mitigate learning effects and improve ecological validity.

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