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Usability Analysis of Graphic User Interfaces for Internet Forums with Consideration for Universal Design Principles

Analiza użyteczności graficznych interfejsów użytkownika forów internetowych z uwzględnieniem zasad projektowania uniwersalnego

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Abstract
Universal design is about creating applications to be accessible to a wider range of users. The paper presents the methodology and results of study on user interfaces of online forums. The main aim of the study is to conduct a comparative analysis of two internet forums. For the purposes of the study, the following research hypothesis was defined: "The application of universal design principles (UDP) increases the accessibility of online forums". In order to conduct the study, the "Elektroda" Internet forum was selected, which does not apply the principles of universal design. Additionally, the authors own Internet forum has been created to meet the universal design principles. An experiment was designed consisting of an eye-tracking tool, the LUT (Lublin University of Technology) and the SUS (System Usability Scale) surveys. 22 participants, students of master's studies in computer science at the Lublin University of Technology, were involved in this study. An evaluation of two web services has also been carried out using the WAVE (Web Accessibility Evaluation) tool. The results of the conducted research confirmed the hypothesis, showing that the application of universal design principles increases the accessibility of online forums.

Keywords: accessibility; universal design; eye tracking; WAVE

Streszczenie
Projektowanie uniwersalne (PUN) polega na tworzeniu aplikacji dostępnych dla szerszego grona użytkowników. Artykuł przedstawia metodologię i wyniki badań dotyczących interfejsów użytkownika forów internetowych. Głównym celem badania było przeprowadzenie analizy porównawczej dwóch forów internetowych. Na potrzeby badania zdefiniowano następującą hipotezę badawczą: „Zastosowanie zasad projektowania uniwersalnego zwiększa dostępność forów internetowych” Do przeprowadzenia badań wybrano forum internetowe „Elektroda”, które nie stosuje zasad projektowania uniwersalnego. Na potrzeby tego przedsięwzięcia autorzy stworzyli własne forum internetowe, które spełnia zasady projektowania uniwersalnego. Zaplanowano eksperyment składający się z badań wykorzystujących narzędzia eye-trackingowe, ankiety LUT (Lublin University of Technology) oraz ankiety SUS (System Usability Scale), w których udział wzięło 22 respondentów. Byli oni studentami studiów magisterskich informatyki Politechniki Lubelskiej. Przeprowadzone również zostały testy aplikacji z użyciem automatycznego narzędzia ewaluacyjnego WAVE (Web Accessibility Evaluation). Wyniki przeprowadzonych analiz potwierdziły postawioną hipotezę, wskazując, że zastosowanie zasad projektowania uniwersalnego zwiększa dostępność forów internetowych.

Słowa kluczowe: dostępność; projektowanie uniwersalne; okulografia; WAVE

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1. Introduction

In the contemporary digital landscape, the usability of graphic user interfaces (GUIs) plays a pivotal role in ensuring an inclusive and accessible online experience for diverse user groups. Usability is essential as it directly impacts the quality of user interaction with a system, application, or website. Usability encompasses characteristics such as efficiency, satisfaction, ease of learning, and memorability, which are crucial to ensuring that users can effectively achieve their goals within a given system. In the context of websites [1], usability holds particular importance since users often need to independently understand and navigate the interface. If a website is difficult to use, users may become frustrated, leading to negative experiences and potential customer loss. Research shows that websites with better usability, especially those that adhere to universal design principles, are more efficient and provide greater user satisfaction. Additionally, it is important to note that usability also affects accessibility [2], which is critical for individuals with disabilities. Improving usability enhances the overall experience for all users.

This study endeavours to delve into the intricacies of internet forum interfaces, specifically exploring their usability through the lens of universal design principles.

The aim of the work is to investigate the hypothesis that *"The use of universal design principles increases the accessibility of online forums"* by conducting a comprehensive analysis of graphical user interfaces of online forums. The goal of the study concerns the approach to creating applications so that each user can operate them independently without any difficulties. A set of standards

was verified according to which user interfaces should be created to ensure usability and accessibility. The study compared two online forums: one created in accordance with the requirements of universal design and the other, which did not meet these criteria. The analysis included an assessment of compliance with WCAG 2.0 guidelines, eye tracking tests and SUS and LUT surveys.

2. Related works

The article [3] presented an assessment of user interface usability using the heuristic evaluation method. This method involved a group of evaluators analyzing the interface design and formulating their opinions about it. The article described four experiments that demonstrated individual evaluators were relatively poor at identifying usability issues, finding only between 20% to 51% of the problems in the interfaces they assessed. However, aggregating the evaluations from multiple evaluators significantly improved the assessment results, even if the group consists of only three to five people. The authors argued that using a set of simple heuristic principles could be an effective and practical way to improve the usability of interfaces in real-world industrial projects. Although heuristic evaluation was challenging, it was valuable. Individual evaluators might miss many issues, but groups of evaluators, working independently, could substantially improve the quality of the evaluation.

The scientific scope [4] described a usability assessment study of an eye tracking tool in the context of using Google Classroom. The aim of the study was to examine how the use of an eye-tracker affects usability test outcomes and user satisfaction. Sixteen respondents participated in the study were divided into two groups. One group performed tasks in Google Classroom without the use of an eye-tracker, while the other group used the eye-tracker. Subsequently, the task completion times and the level of user satisfaction, measured using the USE (Usability, Satisfaction, Ease of Use) questionnaire, were compared. The study results showed no significant difference in time required to complete the tasks between these two groups. However, users utilizing the eye-tracker experienced some discomfort, which could have impacted on their overall satisfaction with the tool. The satisfaction level of users using the eye-tracker was lower compared to those who did not use it.

The publication [5] analyzed the usability of webpage layouts for agricultural products using eye-tracking technology. The authors conducted an experiment involving 30 students, examining their interactions with various e-commerce interfaces dedicated to the sale of agricultural products. The study assessed different page layouts and product list densities to identify optimal settings that enhance search efficiency and improve user experience. The results of the experiment aimed to provide recommendations for designing web pages that not only capture user attention but also minimize cognitive load and increase browsing and product selection efficiency.

The study [6] presented assessments of visual fatigue using an eye tracking system and regression analysis. The researchers employed eye-tracking technology to measure and analyze signs of visual fatigue during various visual tasks. The article described the data collection methodology, where participants performed visual tasks while their eye movements were monitored using an advanced eye-tracker. The collected data were then subjected to regression analysis to identify key indicators of visual fatigue. The study also showed that changes in eye movement parameters could be effective indicators of visual fatigue. This research aimed to enhance the understanding of the impact of prolonged use of digital devices on eye health and to develop more efficient methods for monitoring visual fatigue. The findings suggest that eye-tracking systems could be useful in various applications, such as computer ergonomics, user interface design, and occupational medicine, where monitoring visual fatigue is crucial for maintaining user performance and health.

In the study [7], the researchers aimed to verify the effectiveness of the System Usability Scale (SUS) as a tool for evaluating the usability of human-computer interaction systems. The SUS, created by John Brooke, has been widely used for over 30 years as a quick and simple method for assessing the usability of various websites, software, and other systems. The study conducted by the authors involves comparing SUS scores with traditional usability test results, based on data from eight different usability studies. The authors analyzed the relationship between SUS scores and user performance in completing tasks without errors. The results showed that there was a significant, though small, correlation between these two measures, suggesting that the SUS could be a reliable tool for comparing the usability of different systems. The study also highlighted that while the SUS was a useful tool, its results should be complemented by other usability measured to obtain a more comprehensive view of system effectiveness.

The article [8] addressed the issue of variability in results obtained using different automated web accessibility evaluation tools. The authors emphasized that such variability could mislead users, making it difficult for them to understand the results and limiting the practical utility of these tools. The article discussed the need to increase the transparency of these tools, highlighting the criteria that should be met to facilitate users' interpretation of accessibility evaluation results. The authors analyzed how four selected tools (MAUVE++, WAVE, AChecker, and QualWeb) present their capabilities and accessibility evaluation results, focusing on their transparency and understandability for users. The study indicated that tools should provide detailed information about their functionality, including limitations, so that users could make informed decisions regarding the improvement of web accessibility.

In the study [9] described research on the accessibility of websites of 20 Malaysian public universities. This study was conducted using two automated accessibility evaluation tools: AChecker and WAVE. The main objectives of the study included assessing the compliance level of the websites with WCAG 2.0 guidelines and Section 508 standards. The results showed that the compliance level was relatively low. In particular, most websites did

not even meet the minimum accessibility requirements of WCAG 2.0 (Level A). The most significant issues were the lack of alternative text for non-text content, keyboard accessibility, and color contrast. Other issues, such as navigation, adaptability, input assistance, compatibility, empty links, and headers, also needed improvement. Despite the low compliance level, many websites incorporated some accessibility elements in line with Section 508 guidelines. The authors emphasized the importance of continuous improvement of websites to ensure better accessibility for all users, which could also positively impact the institution's ranking in tools like webometric.

3. Methodology

This section presents the research methodology applied in this study. We presented the evaluated applications, the research group and the research scenarios. We obtained data using the eye-tracker tool, the LUT and SUS surveys and the WAVE automated page survey tool. The last part describes the procedure of the experiment.

3.1. Research objects

To conduct the research, two internet forum services were taken into account - those complying and not complying with universal design principles. Each of them encompasses similar goals, capabilities, and functionalities.

Electrly, the service meeting these requirements, was created by the authors for the purpose of the study. It was designed with the intention not to deviate in terms of subject matter, functionality, and operation principles from the existing application not meeting UX (User Experience) norms but to focus only on its good features. The web application was built based on client-server architecture using backend technologies - Node Express, frontend technologies - ReactJS with NextJS framework. The PostgreSQL database was utilized for storing test data. Sample users, categories, posts along with comments were created in the service and assigned to corresponding categories. Additionally, the application includes elements allowing users to enhance page readability (contrast adjustment feature) and language change capability. The entire application runs on a local server in the Node environment.

The second, existing service that served as our reference point for creating a better application is the Elektroda [11] forum. It is one of the most popular technology forums in Poland, bringing together communities, their knowledge and passions from various fields of computer science. The forum allows user to register to share posts from multiple categories, with default visibility to everyone. Each user has the opportunity to address the discussed issue by posting a comment under the post.

In Figure 1 the main view of the created Electrly application from the user's perspective is depicted, while in Figure 2 the main view of the Elektroda base service is shown.

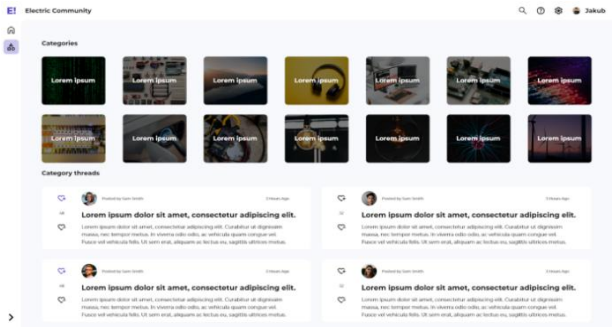

Figure 1: Main view of the created by authors service from the perspective of a logged-in user.

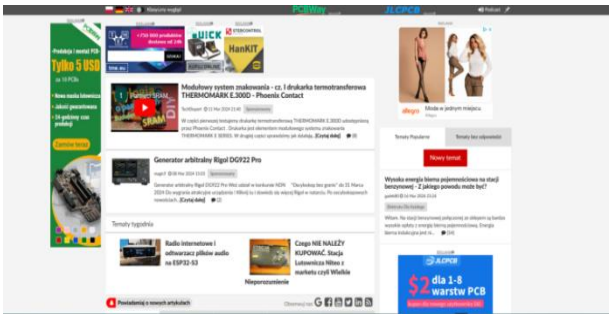

Figure 2: Main view of the Elektroda.pl service.

3.2. Research group

In the conducted study, 22 individuals participated (4 females and 18 males) aged between 21 and 24 years old, the average age was 23.05±0.79. All participants in the study were full-time master's students majoring in computer science at the Lublin University of Technology. Prior to commencing the study, it was established with each participant that they had previous experience with internet forums.

3.3. Eye-tracking study

In this part of the study participants were examined with an eye-tracker device. Below we describe the research stand and the research procedure.

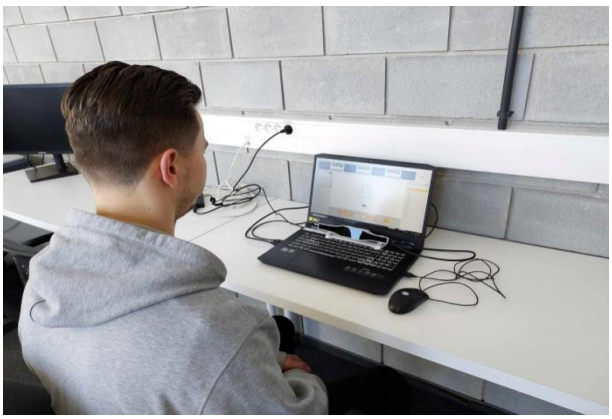

Figure 3: Research stand.

The research experiment was conducted in the laboratory of the Department of Computer Science at the Lublin University of Technology. During the study, necessary conditions to its conduct were provided, including appropriate room lighting, comfortable seating, and

proper distance between the participant and the eye-tracker (approximately 65 cm). In each research session, a moderator was present whose task was to familiarize participants with the purpose of the study and assist them in properly calibrating the tracking device to obtain unbiased results.

As depicted in Figure 3, the research setup consisted of a Gazepoint GP3 HD eye-tracker connected to a laptop with installed Gazepoint Control [12] and iMotions 9.0 software [13]. This software were responsible for conducting the experiment and facilitating the analysis of the data obtained during the study.

The Gazepoint GP3 HD eye-tracker used in the study was placed on a stand above the laptop keyboard. This device enables tracking of both eyes under appropriate conditions with an accuracy of 1° and operates at a frequency of up to 150 Hz. For eye state detection, this eye-tracker model utilizes the bright pupil technique, capturing fixations, blink count, pupil diameter, and saccades.

The mentioned device was connected to an Acer Nitro 5 laptop equipped with a processor AMD Ryzen 7 7800H, Nvidia GeForce RTX 3060 graphics card, 32 GB of RAM, 1 TB SSD storage, and a 15.6" screen with resolution of 1980 x 1080 pixels. The laptop was running the Windows 10 64-bit operating system, along with the necessary Gazepoint Control software for the eye-tracker to function. Additionally, the experiment requires the use of iMotions 9.0, which allows visualization of data through heatmaps, fixation paths, and areas of interest, as well as data export after the experiment is completed.

Table 1: Stages of research

No.	Stage of research
1	Providing participants with necessary information regarding the conducted experiment, its objectives, participant behaviors during the experiment, and assurance of the non-invasiveness of the study.
2	Obtaining participant consent for participation in the study.
3	Calibration of the eye-tracker.
4	Participant completion of displayed instructions until all tasks were completed.

According to the scenario, each subject is first presented with a view with a command to execute, followed by a view of the application page where users are to find the various items. Each subject proceeded to carry out the instructions in turn, with a five-minute interval between each session for the next participant. In each eye-tracking session, they first had to solve tasks related to the view of the website created by the authors, and then to the Elektroda website. Each participant could take part in the experiment only once. Once the command is completed, the user moves to the next view command upon pressing the spacebar. A key aspect of the study is the time it takes the user to complete each task. There are 12 commands defined for each application (24 in total), which can be found in Table 2. The different stages of the eye-tracking study are shown in Table 1.

Table 2: Commands in the study

No.	Command description
1	Locate the element enabling the creation of a new post
2	Locate the element enabling search
3	Find the most popular post
4	Find the "programming" category
5	Find the user "Liteon Abc"
6	Locate the element enabling finding an answer to the question: "My language is not on the list!"
7	Locate the element enabling language change to Polish
8	Locate the element enabling application theme change
9	Locate the element enabling login
10	Locate the element enabling user account creation
11	Locate the element enabling marking a post as helpful
12	Locate the element enabling commenting on a post.

3.4. Survey study

The second stage involved the administration of a surveys assessing interface quality. The same participants took part in the study as in the eye-tracking study.

3.4.1. LUT

First, the respondents completed the LUT [10] survey. Participants evaluated the degree of compliance with universal design principles for selected steps, based on a 5-point scale. In the survey assessing user satisfaction with the quality of the two interfaces, the LUT checklist was utilized, comprising:

- 32 questions rated on a scale of 1 to 5;
- 5 areas divided into 14 subareas, each meeting specific criteria regarding the quality and behavior of the application interfaces.

This tool allows determination of the level of interface execution and application usability. After conducting the study and gathering results, the Web Usability Points (WUP) index is calculated, ranging from 0 to 5.

$$WUP = \frac{1}{n_a}\sum_{i=1}^{n_a}\frac{1}{s_i}\sum_{j=1}^{s_i}\frac{1}{q_{ij}}\sum_{k}^{q_{ij}} p_{ijk} \qquad (1)$$

where: n_a - number of areas, s_i - the number of sub-areas in area i, q_{ij} - the number of questions in area i and sub-area j, p_{ijk} - evaluation of question number k in area i and sub-area j.

3.4.2. SUS

Following the LUT survey, respondents completed the System Usability Scale (SUS) [14] questionnaire consisting of 10 questions. Each question is rated on a five-point scale from 0 to 4, where for even questions 0 means

"strongly disagree" and 4 means "strongly agree," and for odd questions the scale is reversed.

The survey score is calculated by adding up the number of points from each question, and then multiplying it by 2.5. After calculating the average for each respondent, a final SUS scale score is obtained from 0 to 100.

$$\text{SUS} = \left(\sum_{i=1,3,5,7,9} (X_i - 1) + \sum_{j=2,4,6,8,10} (5 - X_j) \right) \times 2.5 \qquad (2)$$

where: X_i represents the value of the response to odd-numbered questions (1, 3, 5, 7, 9), X_j represents the value of the response to even-numbered questions (2, 4, 6, 8, 10), the sum of the scores for odd-numbered questions is $X_i - 1$, the sum of the scores for even-numbered questions is $5 - X_j$.

3.5. Accessibility evaluation study – WAVE

The tested applications were subjected to an accessibility assessment using the free browser extension WAVE Evaluation Tool [15] designed to analyze their compliance with WCAG 2.0 standards [16, 17]. The analysis was performed by two IT engineers specializing in web services. Two views for each application were analyzed. The results of the study were compiled and presented in the next section in the form of tables containing the number of errors for each category and graphs containing the percentage of indicated irregularities.

4. Results

This section presents the results of our study. We described the results of the eye-tracking survey, the results of the LUT and SUS surveys, and the report from the WAVE tool. We performed statistical analysis by averaging the results and calculating the variance and standard deviation. In order to examine the normal distribution and significance of the results, the Levene's and t-Student tests were calculated.

4.1. Eye-tracking study

In this section, we focused on the results of the eye-tracking study. We presented parameters such as: time to first fixation in the area of interest and the number of fixations. The results were subjected to statistical analysis and the results were presented in the form of tables and charts.

4.1.1. Time to first fixation

In this subsection, we conducted the analysis of the first fixation time for applications that meet and do not meet universal design requirements. The aim was to demonstrate the relationship between the use of universal design elements and the time users need to focus their attention on interface elements. It is worth emphasizing that this indicator is a significant element informing about the usability of the interface, as it shows how quickly users can react or identify important interface elements. The mentioned analysis involves comparing the average time for each interface view between the two applications, one meeting and one not meeting universal design standards.

The analysis of the presented data reveals a correlation between the time to the first fixation (TTFF) and both compared applications. In the application adhering to universal design principles, the average times to the first fixation were lower for 9 out of 12 examined views. The conducted statistical analysis also confirmed the existence of differences between the application employing universal design principles and the one not adhering to these principles. The obtained results suggest that the implementation of appropriate practices in interface design may have a positive impact on effective user interaction with the interface. These conclusions can be of significant importance for interface designers, encouraging them to incorporate universal design principles into the application development process.

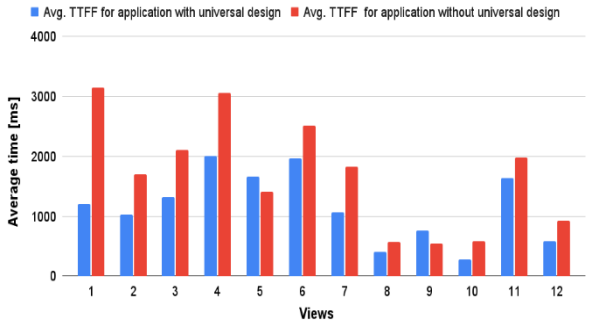

Figure 4: Average time to first fixation.

4.1.2. Fixations number

In the subsequent subsection, an analysis of fixation number was conducted for the compared applications. The aim was to determine the impact of arranging interface elements according to universal design principles on user perception. The number of fixations can be a significant indicator of interface usability, as it informs whether elements on the webpage have been appropriately positioned. The analysis includes comparing the number of fixations for all views of both applications, one adhering and one not adhering to universal design principles

The data presented in Figure 5 depicts the average fixation numbers for each view across both applications. A notable observation is that in the application adhering to universal design principles, fixation numbers are significantly lower than in the application not adhering to these principles. Therefore, it can be inferred that the implementation of good practices in web interface design has a very positive impact on fixation number. The statistical analysis also showed a similar correlation in favor of the application adhering to universal design principles. Thus, it can be concluded that the appropriate positioning of elements, while adhering to universal design principles, has a more positive effect on user attention and the ability to locate elements.

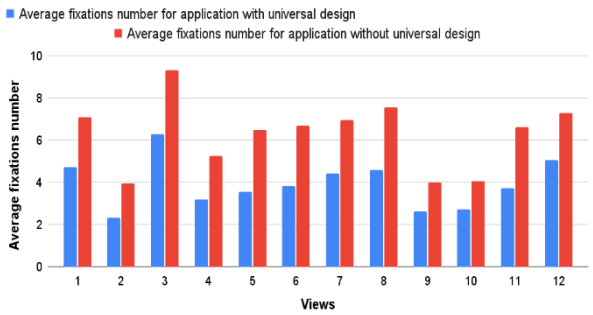

Figure 5: Average fixations number.

4.2. Survey study

In this section, we describe the results of the LUT and SUS surveys for applications with and without universal design. We performed statistical analysis to examine the normal distribution and significance of the data. We identified differences between the examined objects by calculating points according to the adopted methodology. The results are presented graphically.

4.2.1. LUT

The first survey conducted was the LUT survey. The aim of the study was to identify areas for improvement and to determine whether universal design improves results.

Analysis of the results showed differences in the assessment of the application. The universal design application received higher scores in all question categories. Additionally, the results of Levene's test and t-test confirm the statistical significance of the differences between the results for both applications. For average categories of issues, areas and subareas t-test value was 0. However Levene's test value for average categories of issues was 0.86, 0.87 for subareas and 0.93 for areas.

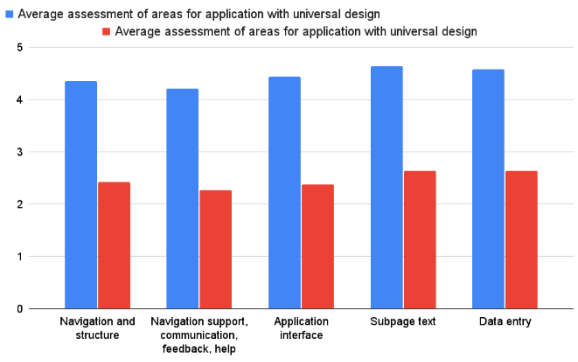

Figure 6: Average assessment of areas of LUT Survey.

4.2.2. SUS

The SUS was the second survey. The aim of the study was to collect users' opinions about the usability of the application. Analyzing the data will help answer whether universal design improves results.

The analysis of SUS results showed significant differences in the assessment of the usability of applications with and without universal design. Apps using universal design received higher ratings, suggesting better interface usability for different user groups. Levene's tests and t-tests confirm the statistical significance of differences between assessments. The t-test value for average assessment of issues was 0 and Levene's test was 0.36.

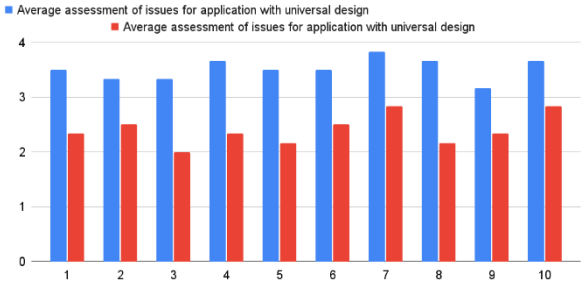

Figure 7: Average assessment of issues of SUS Survey.

4.3. Accessibility evaluation study – WAVE

The final analysis of the results focuses on assessing the accessibility of applications using the WAVE tool. The study was aimed at checking the degree of application accessibility and identifying areas for improvement.

Analysis of the data shows differences in the number of anomalies and guidelines for the application with and without universal design. The application with universal design had significantly fewer irregularities and guidelines. The analysis showed that the application without universal design had significantly more errors related to contrast, missing warnings, and structural as well as ARIA errors.

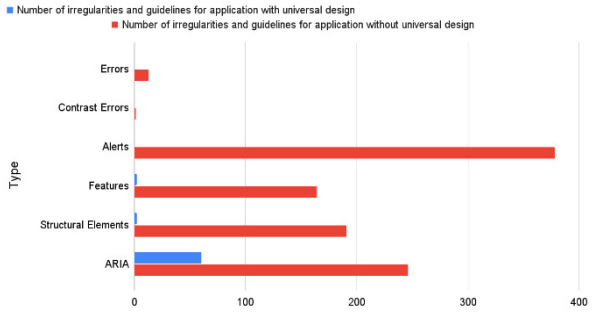

Figure 8: Number of irregularities and guidelines.

5. Discussion

This section will analyze the data obtained from the research conducted to prove the hypothesis: *"The application of universal design principles increases the accessibility of online forums."*. The results of the eye-tracking study, surveys results and the report from the WAVE tool will be discussed. The outcomes of the time to first fixation from the eye-tracking study are very reliable, they enable determining how much time the user needed to find the element from the command. The results of the number of fixations help to determine whether finding an element was intuitive or required searching a larger area of the user interface. The LUT survey allowed one for objective identification of areas of the user interface in which the tested applications differ. The ratings for the subcategories were counted and then the WUP coefficient was calculated. Conducting the SUS survey provided insights into the evaluation of the application's

usability based on the calculated overall score.. The WAVE tool provided information about application non-compliance with WCAG guidelines.

The collected and analyzed results of time to first fixation, allowed us to conclude that for almost all assessed views (with the exception of 5 and 9) where universal design principles were not applied, the average time to locate elements is higher by approximately 165%. Similar, or even greater differences are observed in the case of standard deviation - 158%, and variance - 250%, in favor of the service adhering to universal design principles. Furthermore, the results of confidence intervals and statistical tests such as Levene's test indicated significant differences between data for views adhering and not adhering to universal design principles. Outliers were observed for view 1, where the average sample TTFF results are almost 3 times lower for the application employing universal design principles, while for other views, these values do not differ by more than 50%. The average TTFF results for views 5 and 9 are lower for the application not adhering to universal design principles, most likely because the instructions for the created views for the Elektroda application were formulated in a way that could have potentially guided respondents towards identifying specific elements. For example, in view 5, participants are asked to find the user "LiteonABC," and in the created view, the search result for such a user is highlighted in yellow in the search field, making this element much more prominent and quickly identifiable than in the created application, where respondents had to first locate the section containing users and then visually search through all users to find the mentioned user.

In the next part of the eye-tracking study, we collected and analyzed the average fixation numbers for individual views divided into both applications. Upon examining the obtained results, it is evident that the average fixation numbers for all 12 views of the application adhering to good practices in website interface design are significantly lower. Furthermore, the averages for all 12 views of the application adhering to universal design principles are 63% lower than those for applications not adhering to these principles. Similar dependencies are also observed in the values of variance and standard deviation. For both applications, the confidence interval results had similar values, prompting further statistical analysis through a Student's t-test. This analysis demonstrated a correlation between the average times for all views of both applications, as the value was below the significance threshold of 0.05. Additionally, a Levene's test was conducted, confirming the inequality of variances. Further analysis, with a division into two types of application, also helped draw similar conclusions. These results confirmed the hypothesis that adhering to universal design principles makes it easier for users to locate GUI elements and navigate more confidently within it.

The results from the LUT survey confirm the conclusions drawn based on the eye-tracking study. According to the adopted methodology, the WUP coefficient was calculated for both applications based on ratings on a scale from 1 to 5. The arithmetic mean of the results, standard deviation, variance, Levene's test and t-test were calculated. The average value of the WUP coefficient for applications with universal design was 4.44, and for applications without universal design it was 2.47 so the result for applications with universal design is 80.05% higher. This confirms previous conclusions. Additionally, the application with universal design in the question with the highest score achieved a score of 5.0 for the question “Is the layout adapted to different resolutions?”, and the application without taking into account universal design principles achieved the best score of 3.17 for the question “Is the layout graphically consistent?”. For the lowest scores, the application with universal design received a score of 3.67 for the question “Do they contain hints about problem solving?”, and the application without universal design received a score of 2.0 for the four questions "Is the information hierarchy not too deep?", “Do they contain hints about problem solving?”, “Is the layout clear?” and “Does the color selection enable the use of the application on various displays?”.

The next survey conducted was the SUS survey. The study results confirm the conclusions drawn so far. During the survey, respondents rated their level of agreement with each statement using a Likert scale ranging from 0 to 4. Then, the final SUS points were calculated for both applications according to the formula adopted in the methodology. The arithmetic mean, standard deviation and variance were also determined, and Levene's and t-tests were performed. The application with universal design received an average SUS score of 87.92, and the application without universal design received an average SUS score of 60 SUS points. The score of applications with universal design was 46.53% higher. The research results confirm that an application using universal design is more accessible and achieves higher user ratings. The question with the highest score on a scale from 0 to 4 for an application that meets the principles of universal design is "Most people will be able to master the system very quickly" with a score of 3.83 and the lowest score for the same application was given to the question "I feel very confident using the system” with a score of 3.17 Similarly, for applications without universal design, the highest ratings were given to the questions "Most people will be able to master the system very quickly." and "I had to master many things before using the system" with a score of 2.83 and the lowest rated question was “The system is easy to use” with a score of 2.0.

The last study involved the WAVE tool, which revealed irregularities and guidelines for the application. Based on the results, the mean and sum of parameters and percentages were calculated. The average number of irregularities per page for applications with universal design is 0, and for applications without universal design it is 196±169. In the case of the guidelines, the average amount per page for an application with universal design is 32±1, and for an application not implementing universal design principles is 300.5±180.5. Moreover, the sum of irregularities on all tested webservices is 0 for the application implementing WCAG rules and 378 for applications without these rules. The application with

universal design has a total of 64 guidelines, and the application without universal design has 601 guidelines, so 839% more. It follows that for applications with universal design, irregularities are 0% of all detections, and guidelines are 100%. Similarly, for an application that does not implement universal design, the irregularities are 38.61% and the guidelines are 61.39%. This confirms that applying the principles of universal design makes the application more accessible and has fewer errors.

6. Conclusions

The presented results confirm the hypothesis that *"The application of universal design principles increases the accessibility of online forums"* The study shows that applications that apply the principles of universal design perform better in tests, are more intuitive and receive better user ratings. Additionally, our research confirms that universal design benefits users by increasing application satisfaction and usability, and on the business side by reducing errors and increasing customer satisfaction. Our conclusions complement the reviewed literature, which suggests that implementing the principles of universal design is crucial to ensuring digital accessibility for all users, regardless of their individual needs and limitations.

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