JOURNAL of COMPUTER SCIENCES INSTITUTE

JCSI 33 (2024) 277–284
Received: 16 June 2024
Accepted: 16 September 2024

Accessibility and usability analysis of online museum's graphical user interface

Analiza dostępności i użyteczności graficznego interfejsu użytkownika internetowego muzeum

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Abstract

The aim of this paper was to analyse the accessibility and usability of the graphical user interface of web services: the proprietary web application implemented with the principles of universal design and the website of the Biłgoraj Land Museum not meeting these principles. The experiment involved 15 participants and consisted of two parts: the eye tracking and the surveys. In the first one, an eye tracker was used to acquire times to the first fixation of the area of interest, fixation count and scan paths. The second one used the LUT and QUIS surveys to examine the usability and respondents' satisfaction with both systems. It was proven that the time to locate the elements is shorter for a system meeting the principles of universal design. It was found that satisfaction with the interface rises when it is adjusted to the user's main needs.

Keywords: accessibility; usability; graphical user interface; eye tracking

Streszczenie

Celem artykułu była ocena dostępności i użyteczności graficznego interfejsu użytkownika serwisów internetowych: autorskiej aplikacji muzeum zaimplementowanej zgodnie z zasadami projektowania uniwersalnego oraz aplikacji Muzeum Ziemi Biłgorajskiej niezgodnej z tymi zasadami. Eksperyment, w którym wzięło udział 15 uczestników, składał się z dwóch części: eyetrackingowej i ankietowej. W pierwszej z nich użyto eyetrackera, aby uzyskać czas do pierwszej fiksacji obszaru zainteresowania, liczbę fiksacji i ścieżki skanowania. W drugiej natomiast wykorzystano ankiety LUT i QUIS, aby ocenić użyteczność i zadowolenie badanych z obu systemów. Udowodniono, że czas wyszukania elementów jest krótszy dla systemu zgodnego z zasadami projektowania uniwersalnego. Stwierdzono, że satysfakcja z interfejsu wzrasta, gdy jest on dopasowany do głównych potrzeb użytkownika.

Słowa kluczowe: dostępność; użyteczność; graficzny interfejs użytkownika; eyetracking

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1. Introduction

In response to the continuously increasing role of public websites in the scientific and cultural domains, with a particular focus on websites that improve the functioning of museum institutions, there is a growing need to develop web services that can reach the widest possible group of people [1]. For this purpose, the principles of universal design may be applied, increasing the accessibility and usability of museums' graphical interfaces, both for healthy people and people with disabilities or various types of limitations. The goal of this study is to examine the impact of universal design principles on the accessibility, usability, and user satisfaction of a museum's graphical application interface by comparing two versions of the interface: one that conforms and one that does not conform to the principles of universal design. The following hypotheses served as the basis for this study:

H1. The time required for the user to perform a specific action or to locate an element in the museum's graphical user interface is longer for an application that does not comply with the principles of universal design, compared to an application developed in compliance with these principles.

H2. The quality of the interface and user satisfaction are higher when the interface has been implemented taking into account the universal design principles.

2. Related works

The universal design principles (UDP) should be considered in the process of designing and implementing the GUI (Graphical User Interface). One of the employed experiments for various types of evaluations that we have found by studying scientific literature is the eye tracking method. This technique involves gaze tracking of the user participating in the study. Very often, the eye tracking method is used in conjunction with other techniques or is only applied as an additional metric. The paper [2] focused on discussing various techniques of eye tracking for analysing users' scan paths on web pages. The authors determine and compare the effectiveness and limitations of chosen techniques, providing conclusions on how users process visual stimuli, allowing for the optimization of usability and accessibility of graphical web interfaces. The article [3] aimed to examine the layout of the design page and the most eye-catching elements in order to implement services across various industries. The study was conducted using a questionnaire and neuromarketing methods based on eye tracking. The results suggested that the upper, central, and right sections of web pages attract the most attention. The article [4] aimed to investigate the practicality of the online Hacettepe University Registrar's Office website. The authors used the case study method for their research. Their objective was to carry out tasks that are frequently used by students during their course of study. The findings indicated that the navigation and the visual aspect of the website require some improvements dedicated to adjusted drop-down menus, shorter pages or minimised banner height. The article [5] focused on how the selection of colour combinations and their contrast in user interfaces affects the compliance with the accessibility guidelines, usability and user preferences, through objective measurements of visual intensity using eye tracker and subjective user predilections. The authors point out the need to follow WCAG (Web Content Accessibility Guidelines) standards in web design while adapting to users' personal preferences.

Another relatively prevalent method is the one that uses questionnaires. It usually represents a complementary approach to the use of the eye tracker. The study [6] illustrated that the visual attractiveness of websites has an extensive impact on users' perception of usability. For this purpose, the authors used a questionnaire and an eye tracker method. The findings suggested that web page elements such as large images, celebrity photos, minimal text and a search function are more attention-engaging for Generation Y people. Similarly, a technique combining the use of online survey and eye tracker was utilised in the study [7] to formulate a number of recommendations for the improvement of reading performance on a computer screen. Analysis of the data indicated that higher contrast and larger font size have a positive impact on reading. The suggested recommendations include a stronger contrast between font and background colours, larger font sizes and specific spacing or colour configurations. In the paper [8], the usability of 2 local e-government websites in Taiwan was assessed and a questionnaire method was used for this purpose. The authors suggested that the identified flaws can be a reference point for evaluating and improving other e-government sites. The article [9] delved into the challenges of designing web pages that prioritise user needs, with a particular focus on university websites. The study involved surveying students to assess the effectiveness and usability. It pointed out notable deficiencies in satisfying the basic usability standards expected by students, which negatively affects navigation efficiency, accessibility and user satisfaction.

An alternative approach for evaluating GUIs may be the use of automation tools. Such a solution does not require the use of an eye tracker and can be performed in a very short period to quickly analyse the compatibility of websites with various standards. In the paper [10], the authors proposed the use of automated web testing tools (SortSite and WebAIM WAVE) for selected websites of Ghana's metropolitan assemblies. The proprietary Double Evaluation Technique (DET) was also proposed, which consists of two different methods for evaluating websites – based on SortSite tool and WCAG compliance. In the research, scientists found serious problems with accessibility, compatibility and usability on the examined websites. The majority of websites were found not to follow heuristic guidelines and standards. The authors in the paper [11] proposed the evaluation of 11 e-learning websites from the Middle East using the EvalAccess tool for measuring the content accessibility and the Linkchecker tool for scrutinising the usability. For verification of the website performance, the Pingdom software was used. The researchers found that the websites did not meet usability and accessibility standards, drawing attention to incompatibility with WCAG guidelines, complex navigation, lack of information readability and broken links. In the article [12], the topic of Internet accessibility was addressed with particular attention to people with disabilities. The study utilised 25 Malaysian federal government websites, which were tested against the WCAG 2.0 guidelines. Two objective tests were conducted using AChecker and WAVE tools. The findings revealed that significant concerns are keyboard accessibility, with 29% of errors reported, and empty form labels, accounting for 33% of total errors. Other notable issues include empty links, problems with contrast, navigation and missing alternative text for linked images which highlights the need for improvement of web accessibility on these websites. In the study [13], the researcher focused on assessing WAVE and SiteImprove website evaluation tools, which was conducted in terms of accessibility, using 6 homepages from the Saudi public universities. Common problems such as empty links, lack of alternative texts for images and missing image alt attributes were detected on the examined websites. The authors [14] undertook the task of describing the metrics for the usability of websites using the MUG (Multi-category Usability Grading) method. The study participants were asked to assign weights to the various usability categories and then rated websites based on these criteria. The respondents identified content as the most important aspect of a website, followed by ease of use and usability. Ratings varied across different industries and tasks.

3. Materials and methods

To perform the analyses of the online museum's GUIs, it was chosen to use diverse techniques such as the eye tracking method, as well as LUT (Lublin University of Technology) and QUIS (Questionnaire for User Interface Satisfaction) surveys. The study consisted of the following stages:

- an eye tracking study to obtain qualitative data in the form of scanning paths and the results of eye tracking metrics such as time to first fixation in the area of interest (TTFF AOI) or fixation count;
- verification of the accuracy of the performed instructions, analysing and rejecting erroneous cases;
- conducting surveys on the usability of the GUI (LUT) and user satisfaction with the system (QUIS).

3.1. Selected and developed web services

One web service of the museum was selected and a proprietary application was designed so that both could satisfy the functional requirements in a similar but to the greatest possible extent.

The first web application is the web service that has been implemented for the purposes of this study. The application's graphic interface allows for simple and intuitive use of the application regardless of age, level of disability or computer skills. It has been implemented in accordance with UDP. Hereinafter, the abbreviation CPUD application (Conforming with the Principles of Universal Design) will be used.

The second web service is a public website of Biłgoraj Land Museum in Biłgoraj (https://muzeum-bilgoraj.pl/) that allows visitors to find out about its latest historical or educational projects and the exhibitions taking place at the museum. Due to clearly discernible issues such as complex navigation structure, illegible content, low contrast, excessive amount of information on the pages, the service will be treated as an application that does not meet UDP and will be used to make comparisons with the CPUD application. Therefore, the abbreviation NCPUD application (Not Conforming with the Principles of Universal Design) will be used.

3.2. Participants

The study involved 15 people who were randomly selected from among master's degree students of computer science at the Lublin University of Technology. The research sample included 14 men and 1 woman, and the average age of participants was 23.2 with a standard deviation of ±0.54. The respondents also included people with visual impairments (1 person with daltonism, 5 persons with myopia and 2 persons with astigmatism). The main attribute of the research participants was their high ICT (Information and Communication Technology) skills – the respondents are considered to be advanced users.

3.3. Eye tracking study

The first stage in the experiment's development involved selecting suitable interface elements from both applications and assigning specific views with properly formulated instructions to be completed by the user. The analysed elements were divided into 2 groups, characterised by the fact whether they were designed according to UDP or whether they do not comply with these principles. One group included views of the CPUD application while the other involved the NCPUD application. The tasks with views were applicable to both groups. The prepared groups of application views and their assigned instructions were imported into the iMotions software. Two separate projects were created in the application corresponding to the research object groups. Subsequently, the research participants were surveyed using these groups. Each participant was involved in both parts of the eye tracking experiment, during which the group of views associated with the CPUD application was displayed first, followed by the views connected with the NCPUD application.

3.3.1. Scenarios

Before the actual test, each respondent went through a calibration procedure. The experiment participants were asked to localise the elements according to the instructions presented in Table 1. The first service tested was the CPUD application, the second was the NCPUD application. The tasks were displayed in the centre of the screen and were performed one at a time. Then, after reading, the respondent pressed the space bar and an image appeared with a test object on which he or she was asked to locate the corresponding item. Once located, they would press the space bar again and so on until all the instructions were completed. Two examples of the home page views for both applications are shown in Fig. 1-2.

Table 1: Tasks to be completed by study participants

No.	The content of the task
1	Find the font size change button
2	Find the button to change the page contrast
3	Find the icon with a link redirecting to the museum's Facebook page
4	Find the link to the exhibition
5	Search for the tab that takes you to the exhibitions page
6	Find information about whether you can take photos of the exhibits
7	Search for information about the latest exhibition
8	Search for a calendar of events
9	Search for museum contact information – address
10	Search for museum regulations
11	Search for the museum information tab
12	Locate the price of concessionary tickets
13	Locate the discount on normal tickets
14	Search for information about the museum's opening hours
15	Search for indicated multimedia
16	Find the link to the FAQ

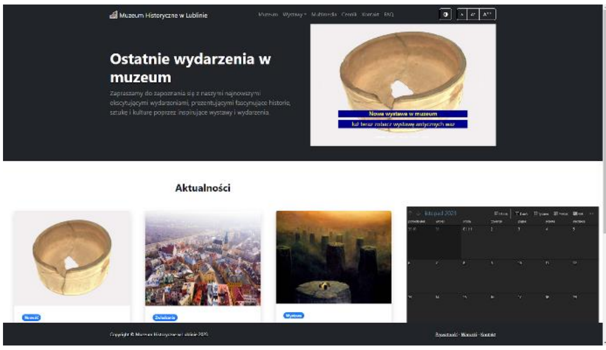

Figure 1: Example view of the CPUD application associated with the command 1.

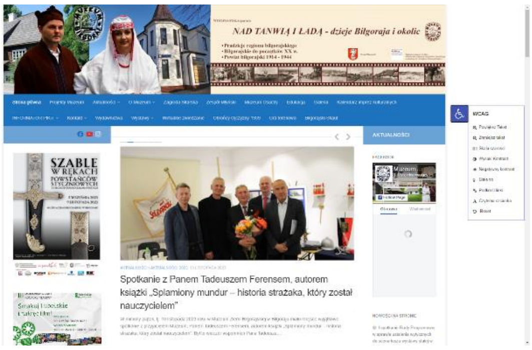

Figure 2: Example view of the NCPUD application associated with the command 1.

3.3.2. Research stand

For the experiment, a research stand was used, consisting of the following components:

- eye tracker from Gazepoint, model GP3 HD [15];
- Acer laptop (model Nitro 5) with a FULL HD screen diagonal of 17.3";
- iMotions software (version 9.0) [16].

In Fig. 3 the research stand for eye tracking is presented. An experiment participant uses a laptop, in front of which a remote eye tracker running iMotions software is placed.

Figure 3: Research stand for eye tracking.

3.4. Survey study

3.4.1. LUT survey

An experiment focusing on content accessibility, with consideration of interface quality, was carried out using LUT surveys [17]. The questionnaire was provided for participants, in which they were asked questions to rate on a scale from 1 to 5. The survey consisted of 26 questions divided into areas and subareas of the application. The example areas include the application interface and the text of the pages, and the sub-areas are layout, colour selection, naming and labelling.

Once the results for the specified application have been obtained, a WUP score has been calculated using formula (1). The WUP score ranges from 1 to 5. A higher value indicates a better designed interface [17].

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

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

3.4.2. QUIS survey

The QUIS survey [18] was used in the study to obtain information about users' satisfaction of the system. It consisted of 23 questions with a rating range of 1-9, where 1 was the weakest and 9 the best. Respondents were asked about organisation, consistency, speed of operation, contrast of the application and difficulty of use. After receiving the results, the average score was calculated: the higher the average, the higher is the user's satisfaction with the app.

4. Results

4.1. Eye tracking study

After conducting the study according to the scenarios presented in subsection 3.3.1, the total number of 480 eye tracking recordings was obtained in the form of detailed data including measurements of TTFF (AOI) times, fixation count and scan paths for each participant in the study. This number is a result of surveying 15 respondents using 16 commands in two applications. The eye tracker recordings were exported via iMotions software. The raw quantitative data was then processed appropriately so that it could be analysed for further purposes.

Based on scan paths, the retrieved results were verified to ensure that the instructions were correctly executed by respondents which consisted of selecting typical and atypical visual behaviours of participants in response to displayed stimulus and task. Among all the results, 21 command-related results were discarded where participants failed to find a specific element or found an incorrect element with the one specified in the task. Measurement data with missing or zero values were excluded so as not to interfere with the analysis findings. As a result, a total of 459 results were taken into consideration.

In Fig. 4-5 scanning paths associated with the command 3, showing the users' actions in the interface, are presented. It can be observed that the CPUD application (which used high contrast) had fewer fixation number and significantly shorter scanning paths than in the NCPUD application (that used low contrast), indicating that it was easier to find the specified element.

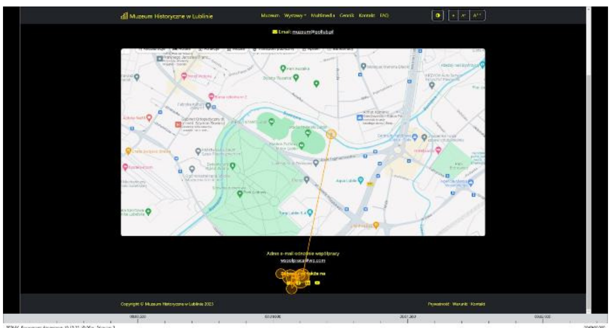

Figure 4: Example of scanning path for the CPUD application.

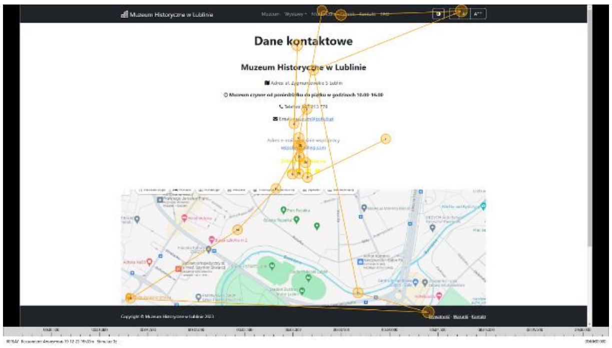

Figure 5: Example of scanning path for the NCPUD application.

4.1.1. Measurement of times to first fixation (TTFF)

The average of TTFF (AOI) times for each command for both applications were calculated. The data was collected in a tabular form, and then graphs were prepared compiling the average TTFF (AOI) times depending on the task performed by the participant for both applications. Comparing TTFF (AOI) times in both applications, it was possible to note a significant difference in time task performance. As can be seen in Fig. 6-7, in most cases the execution of tasks in the CPUD application was up to twice as fast as the tasks associated with the NCPUD application. The TTFF (AOI) time of locating the elements was on average 0.992 s shorter for the CPUD application, indicating that the level of difficulty of finding these elements was low.

However, three cases can be observed in which the average execution time of tasks in the NCPUD application was shorter than in the CPUD application. For task 10, respondents found the link to the museum's regulations in the NCPUD application faster by 0.324 s than in the CPUD application. This was due to the fact that the link of the NCPUD application was directly below the map, which took up most of the screen space, making it easier to locate. In the case of the CPUD application, respondents additionally had to analyse the column of information on the left-hand side of the screen before moving to the column on the right, where the button with the link was placed.

The faster performance of task 13 by 0.665 s for the NCPUD application was due to the fact that in the NCPUD application, the price of normal tickets was listed on the central part of the screen in a larger font. In the case of the CPUD application, four different offers could be found among the ticket prices on the page, where the price of normal tickets was located at the right-hand edge of the screen, and thus it required the respondents to analyse all offers in order to find the right one. The fact that in the NCPUD application the price of normal tickets was the only price presented in the main section of the page allowed respondents to find the item they were looking for much quicker.

The average execution time of task 16 for the NCPUD application was 1.094 s shorter than for the CPUD application. The difference arises from the fact that the positioning of an element on a page does not always result in finding it more quickly. The link to the FAQ page in the CPUD application, despite being placed in the top navigation bar in a prominent position, took the respondents longer to find than the link placed in the footer in the NCPUD application. Usually, the link to the FAQs is at the bottom of the page, so if users are unfamiliar with that, the habit will still have a crucial role to play when searching for a particular item.

In Fig. 6-7 a comparison of the average times to first AOI fixation in both application interfaces depending on the task performed by the participant is shown.

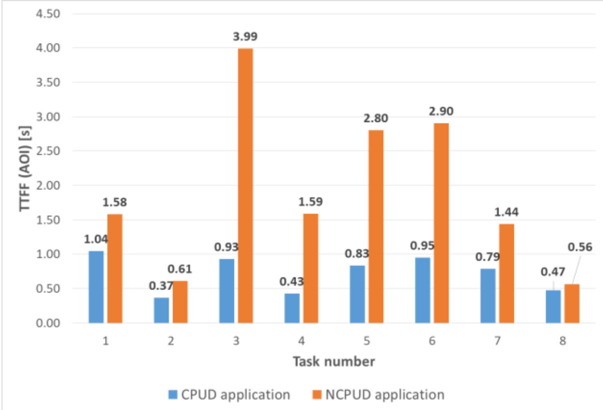

Figure 6: Comparison of average times to first AOI fixation in the interfaces of the CPUD and the NCPUD application for tasks 1-8.

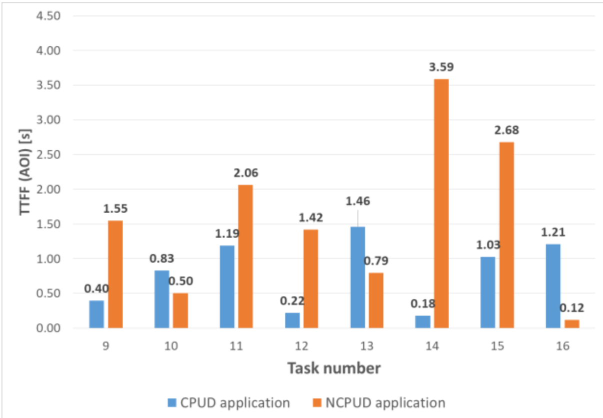

Figure 7: Comparison of average times to first AOI fixation in the interfaces of the CPUD and the NCPUD application for tasks 9-16.

In Fig. 8 a bar chart of the average TTFF (AOI) for all tasks in the compared applications is shown, with confidence intervals indicated by error bars.

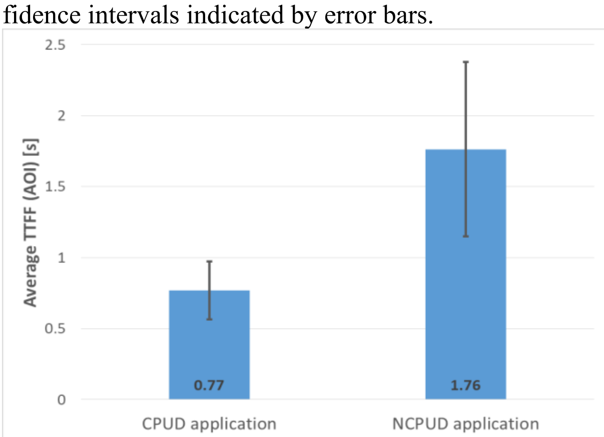

Figure 8: The average time to first AOI fixation for all tasks in the compared applications, with the marked confidence intervals as error bars.

A Student's t-test was then performed for a 95% confidence interval. For the time to first AOI fixation in this test, a p-value of 0.00272 was obtained, which meant that there was a 0.272% chance that the difference between the two average TTFF (AOI) times was not significant. As a 95% confidence interval was imposed, the result obtained was less than 5%, so the difference at this level was statistically significant.

In Fig. 9 the summary of statistics for testing the significance of differences between the studied characteristics for the view associated with the command 3 is presented. The p-value of ANOVA analysis was 0.00195, proving the statistical significance of this result.

SUMMARY

Groups	Count	Sum	Average	Variance
CPUD application [s]	12	11.38356	0.94863	0.26826
NCPUD application [s]	12	47.68102	3.973418	8.617625

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	54.89607	1	54.89607	12.35579	0.001952	4.30095
Within Groups	97.74475	22	4.442943			
Total	152.6408	23				

Figure 9: Single-factor analysis of variance ANOVA for command 3.

4.1.2. Measurement of the fixation count

The next step was to conduct an analysis based on fixation counts, which included gathering data and preparing graphs presenting the recorded average number of fixations depending on the task performed by the participant for both applications. Similar to the results presented in Fig. 6-7, in most cases the values of the average number of fixations were similar or even significantly lower for the CPUD application in comparison to NCPUD application, with the maximum difference reaching up to 10.48 fixations.

However, four cases can be observed in which the average fixation count in the NCPUD application was lower than in the CPUD application. In task 8, the difference in number of fixations was 1.48 and was a result of the location of the events calendar. In the case of the CPUD application, the calendar was located at the right edge of the screen. Despite its larger size, it required a more focused gaze for respondents to analyse the whole page content. It was also accompanied by a higher number of fixations than in the NCPUD application, where the calendar was positioned at the top left of the screen, where most users started their search for elements. This made it much quicker for users to find the item they were looking for.

For command 9, the difference in the fixation count was 1.8, while for command 14 it was 2.43. In both cases, the average number of fixations for the NCPUD application was lower than for the CPUD application and was due to the fact that in the CPUD application the information the participants were supposed to find was on a single line of the text, whereas in the NCPUD application the text was broken into several lines. A text written in one long line may require more horizontal eye movements, which can lead to more eye fixations than in text broken into multiple lines. Moreover, a text that does not contain breaks or indentations hinders visual orientation.

The number of fixations in command 15 for the NCPUD app was 6.56 fewer than in the CPUD application. This may be due to the fact that in the NCPUD application, users had to examine a gallery consisting of just the photos in a smaller size, whereas in the CPUD application there were large photos containing text and captions underneath. The presence of text made it necessary to analyse additional information, which had the effect of increasing the number of fixations.

In Fig. 10-11 a comparison of the average fixation count in both application interfaces depending on the task performed by the participants is presented.

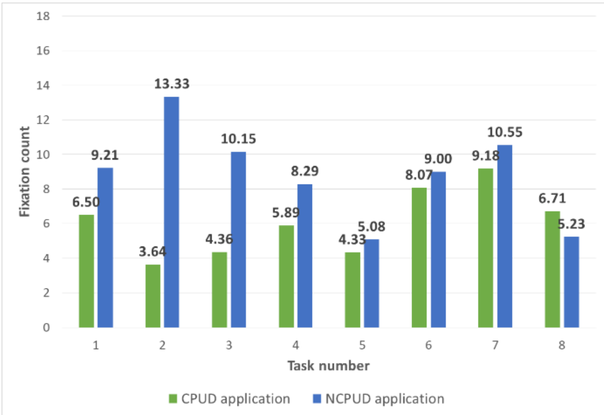

Figure 10: Comparison of average fixation count in the interfaces of the implemented and compared application for tasks 1-8.

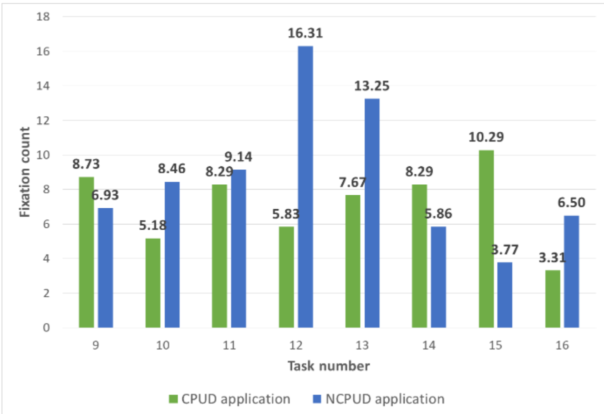

Figure 11: Comparison of average fixation count in the interfaces of the implemented and compared application for tasks 9-16.

A Student's t-test was then performed for a 95% confidence interval. For the fixation count in this test, a p-value of 0.03697 was obtained, which meant that there was a 3.697% chance that the difference between the two average fixation counts was not significant. As a 95% confidence interval was imposed, the result obtained was less than 5%, so the difference at this level was statistically significant. In Fig. 12 a bar chart of the average fixation count for all tasks in the compared applications is presented, with confidence intervals indicated by error bars.

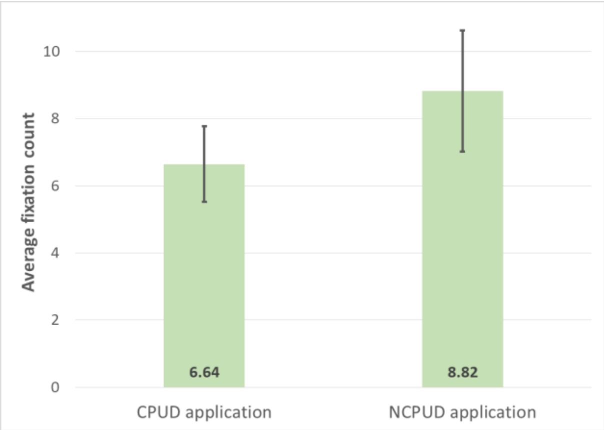

Figure 12: The average fixation count for all tasks in the compared applications, with the marked confidence intervals as error bars.

4.2. Survey study

According to the results of the LUT survey, WUP metric values were calculated for both applications. The WUP score for the CPUD application was a value of 4.53. For the NCPUD application, it was a value of 2.5. The analysis of the calculated value of the number of WUP points for both applications made it possible to indicate that the quality of the interface of the CPUD application was definitely higher in the respondents' opinion than the interface of the NCPUD application.

Based on the results obtained in the QUIS survey, an average value was calculated for both applications. For the CPUD application, the value was 8.31 and for the NCPUD application was 3.82. The average number of points granted by the respondents helped to confirm that satisfaction with the quality of the CPUD interface was higher than NCPUD application and, therefore, the interface which was implemented taking into account the main functional requirements as well as according to the user's needs was of higher quality.

5. Discussion

The study that has been carried out to prove hypotheses H1-H2 provided the extensive research results which have been analysed in detail. The most relevant studies were considered by the authors to be those based on the eye tracker, which provided not only numerical results, but also scanning paths that allowed to verify the correctness of participants' tasks performance. Subsequent research using specialised questionnaires provided information on users' satisfaction with the system and detailed analysis of individual pages of the interface.

The quantitative analysis has brought the expected results. Average TTFF (AOI) times for each command were calculated for both applications. Out of the 16 tasks conducted, the CPUD application proved to be better in 13 tasks – the times for the CPUD application were twice as fast as in the NCPUD application, and the shorter element location time indicates that the difficulty level of the elements search is lower than in NCPUD application. TTFF (AOI) times were on average 0.992 s shorter for the CPUD, confirming the hypothesis H1: *The time required for the user to perform a specific action or to locate an element in the museum's graphical user interface is longer for an application that does not comply with the principles of universal design, compared to an application developed in compliance with these principles*.

Another aspect of the quantitative analysis was the study on the average number of fixations for each command for both applications. Out of the 16 tasks conducted, the CPUD application proved to be better in 12 tasks – the fixation count for the CPUD application was lower on average by a value of 2.17, which suggests that CPUD application is easier for the user to use and more practical. It can also imply premises concerning the validity of the hypothesis H1, because the lower number of fixations is associated with the better quality of the CPUD application's graphical interface.

A one-way ANOVA was also performed separately for TTFF times (AOI) for individual tasks. In all cases it was proven that there is a significant impact of the evaluated interface view on the value of the TTFF variable, and therefore there are significant differences between the two tested characteristics of the TTFF (AOI). Then, the Student's t-test was performed within the 95% confidence interval for both TTFF (AOI) and fixation count, which proved that the difference between TTFF (AOI) times or average fixation number is not significant.

The quantitative analysis made it possible to confirm the validity of the recommendations formulated in the paper [4] for the design of websites to increase the accessibility and usability, with particular emphasis on the key areas that were mentioned in the works [9, 12]. Similarly, the applied recommendations in the CPUD application regarding, inter alia, the structure, layout of the information, visual elements, fonts or colours, which were presented in the paper [2], have also increased the visibility and usability of the CPUD application's graphical interface. The guidelines for links made by the authors of the paper [8] were followed in an analogous way, avoiding the usability problems described in the article.

The surveys were carried out using two carefully selected questionnaires, which made it possible to examine the respondents' evaluation of the tested applications in detail. From the LUT survey it can be concluded that there is a clear advantage in the quality of the interface implemented with UDP. The results of the QUIS survey indicated that the level of user satisfaction of CPUD application was more than twice as good as NCPUD application. Both surveys confirmed hypothesis H2: *The quality of the interface and user satisfaction are higher when the interface has been implemented taking into account the universal design principles*, indicating its validity.

However, the study presented in this paper has some weaknesses that should be taken into consideration in the future work. In the case of the eye tracking study, due to the need to exclude some of the erroneous data, additional tests could be carried out to cover the amount of data, which was excluded, so that the results could be more accurate, being concurrently prepared on a larger number of participants. Although the CPUD application was implemented with the use of UDP, it was possible to locate several cases that are considered to have caused the TTFF (AOI) and the number of fixations to be higher than in the NCPUD application. Possible reasons for these discrepancies were provided, it should be noted that they were not directly related to the aspects of universal design, nevertheless they should also be taken into account when designing and implementing web services in future work.

The results collected, presented and discussed above confirmed all the presented hypotheses H1-H2. The study showed that websites designed according to UDP offer a significantly better adapted and perceived interface for users.

6. Conclusions

The study, which was carried out in accordance with the established research methodology, allowed to demonstrate the validity of the hypotheses and also confirmed observations made by the authors of other papers that this work refers to. The study emphasises the importance of designing user interfaces that are intuitive, accessible and visually appealing, paying attention to the diverse needs and preferences of the users. The research clearly proves that the utilisation of UDP in the design of the muse-um's online GUIs has a significant impact on accessibility, usability and user satisfaction with the system. The detected inconsistencies in the results represent some limitations of this work, however, they are not strictly related to aspects of UDP, but should be taken into account in the future studies.

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