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Analysis of graphical user interfaces of music services taking into account universal design principles

Analiza graficznych interfejsów użytkownika serwisów muzycznych z uwzględnieniem zasad projektowania uniwersalnego

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Abstract

While creating services, great emphasis is placed on usability and accessibility of the user interface. These elements allow applications to reach the widest possible audience. The purpose of this study was to examine the impact of contrast, font size and Universal Design principles on the usability of music services. The evaluations were carried out with the help of two applications, first that meets and second that does not meet WCAG 2.1 and Universal Design principles. Using eye tracking technology, LUT and SUS surveys and the WAVE tool. Twenty-one participants took part in the eye tracker study. Comparative factors were average times to first fixation, number of fixations and survey results. The results showed that the use of Universal Design principles and WCAG 2.1 has a significant impact on the accessibility and usability of applications.

Keywords: usability; accessibility; user interface; eye tracking

Streszczenie

Tworząc usługi duży nacisk kładzie się na użyteczność i dostępność interfejsu użytkownika. Elementy te pozwalają aplikacjom dotrzeć do jak najszerszego grona odbiorców. Celem badania było sprawdzenie wpływu kontrastu, rozmiaru czcionki i zasad projektowania Uniwersalnego na użyteczność usług muzycznych. Oceny przeprowadzono przy pomocy dwóch aplikacji, pierwszej spełniającej i drugiej niespełniającej zasad WCAG 2.1 oraz projektowania Uniwersalnego. Korzystając z technologii śledzenia ruchu gałek ocznych, ankiet LUT i SUS oraz narzędzia WAVE. Dwudziestu jeden uczestników podjęło się udziału w badaniu okulografem. Czynnikami porównawczymi były średnie czasy do pierwszej fiksacji, liczba fiksacji oraz wyniki ankiet. Wyniki pokazały, że stosowanie zasad projektowania Uniwersalnego i WCAG 2.1 ma znaczący wpływ na dostępność i użyteczność aplikacji.

Słowa kluczowe: użyteczność; dostępność; interfejs użytkownika; eyetracking

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1. Introduction

Nowadays, the web environment is undergoing a very dynamic development, and with this comes the continuous growth of applications available on electronic devices. Given the speed of the changes taking place and the desire to prevent the exclusion of specific user groups, the accessibility of web applications has become a key aspect of design, aiming to make content accessible to the widest possible range of users. The web accessibility guidelines contained in WCAG 2.1 (Web Content Accessibility Guidelines) and the principles of Universal Design (UD) have become the basis approach application development. Applying them makes applications intuitive and accessible to all users regardless of their limitations or needs.

WCAG 2.1 was developed by the W3C (World Wide Web Consortium), is a set of international standards and guidelines focusing on the accessibility of web content for people with different levels of disability [1]. The aim of using these guidelines is to make the information and functions contained in a web application accessible to people with different needs and levels of disability. The guidelines cover areas such as the perception, handling or comprehension of information provided through websites. WCAG 2.1 recommends, among other things, providing content through a variety of media such as text, sound or images, enabling a website to be operated using a variety of devices or ensuring consistency of interaction between the user and the website.

Universal Design represents an approach that aims to create products and applications that are accessible and usable by the widest possible range of users, regardless of their individual preferences, skills or limitations [2]. The basis of UD includes seven principles that delineate areas of application improvement. These are a fair use, flexibility of use, simple and intuitive use, noticeable information, tolerance for error, low physical effort and appropriate dimensions and spaces. Eye tracker devices come to the aid of studying the accessibility and usability of graphical interfaces of web applications [3]. They monitor and record the user's eye movements. The main purpose of an eye tracker is to record fixations, i.e. moments when the eyes focus on a particular object, and saccades, i.e. rapid movements occurring between fixations. Based on the recorded data, it is possible to determine the level of usability or learnability of the user interface under the study. Depending on needs, we can use a static version of the device placed under the monitor displaying the interface under study, or a more mobile recorder in the form of glasses.

2. Related work

This chapter provides a review of the available literature on universal design, the layout of elements in the interface, the impact of contrast, the impact of memorability and readability of the interface, as well as research carried out with an eye tracker and WAVE tool.

2.1. Related work on universal design

Universal Design should be understood as designing products and environments in such a way that as many people as possible can benefit from them, without the need for adaptation or specialised design for each individual. In articles [4, 5], research was carried out to use UD principles to increase accessibility for as many people as possible. The first study is about developing four applications for booking vehicles. All applications were tested by four groups of users, older, younger, disabled and experienced. This allowed them to investigate what elements affect each group. The second one focused specifically on older people and the visually impaired. This used an extensive methodology including user surveys, usability evaluations and studies analysing navigation, text size or colour contrast. In this way, it was verified which principles have a greater impact than others. The results showed that customized designs significantly improved the performance and efficiency of older and disabled users, with a small decrease in performance among younger users. The results showed the need for implementing UD to improve the accessibility of the TV interface with a special emphasis on the importance of contrast.

2.2. Related work on contrast

Good colour contrast is one of the characteristics that a website should have. It is defined as the highlighted difference between details, and it also serves to emphasize and accentuate selected sectors of the website.

In study [6], researchers investigated the effect of colour mode (light and dark) and the effect of contrast alone on visual fatigue. They conducted the study in a low-light environment. The determinants of fatigue were blink frequency and the Likert scale. A similar study [7] was also conducted by other researchers but they focused on mental fatigue. They used existing web applications, but changed the contrasts on them and examined the effect of individual colours with the existing 'The colour-contrast-checker tool'. Both studies indicate that users should choose darker themes at night to reduce visual fatigue.

2.3. Related work on usability

Website usability is about making them functional and easy to use so that users can find their way around easily.

Usability has been investigated in articles [8, 9, 10]. In the first paper, they conducted a study on the usability evaluation of the university website for visually impaired students. Through the use of interviews, usability tests, surveys and the use of qualitative and quantitative tools to collect data. They examined which elements students had problems with. The authors concluded that there is a need to take into account the needs of people with visual impairments when designing websites. The next paper describes a study whose aim was to suggest usability heuristics as an evaluation parameter in usability testing. The study focuses on the application of Jakob Nielsen's 10 usability heuristics to the usability evaluation of public sector university websites. Usability questionnaires and evaluation heuristics were used to conduct the study and the study itself was conducted on the websites of four public universities in Pakistan. The author concluded that Usability Heuristics are an effective tool for evaluating the usability of websites. The third paper explores the relationship between usability and Quality of Experience (QoE) in the context of website use. Participants in the study were asked to perform tasks on a website whose usability and QoE were manipulated and at the end they were unable to independently assess QoE.

2.4. Related works on readability

The readability of a website is a parameter describing how easily users can understand the text on a web page.

Readability was investigated in [11] which describes a study whose aim was to investigate the effect of different interface colour modes on users' reading accuracy. The study used a website design with six colour themes. Eye tracking was used for the experiments to collect data on fixation frequency and saccades. The results of the data analysis showed that appropriate design of text boxes helps participants to focus on the content of the text. In another research paper [12], a study was conducted to evaluate the effect of different background colours on screen legibility for people with and without dyslexia. The study involved 341 participants (89 with dyslexia) who read texts on different background colours. Readability was assessed by reading time and mouse tracking, and comprehension was the control variable. They concluded from the study that warm colours significantly improved reading performance compared to cold colours. In [13, 14], the researchers focused on the text size in the context of the readability of web applications. In the first study, the relationship between font size and the age of users was investigated. The researchers demonstrated that older people need larger fonts than younger people. In the second study, using the most popular fonts, the researchers concluded that the 12-point matrix typeface Arial was preferred over other typefaces.

2.5. Related works on eye tracker

The eye tracker is a device that tracks eye movement. It works by sending infrared light, then the light is reflected in the user's eyes and finally captured by the eye tracker's cameras.

Studies using eye trackers has been described in articles [15, 16, 17]. The aim of the first paper was to test the application and methodology of eye tracking in different domains using eye trackers from different companies. The results demonstrate the versatility of the eye tracking technology of the various eye trackers. The second examined hypotheses related to user perception when performing end-user tasks. The study involved a group of 10 participants, eight of whom successfully completed the task. The results showed significant correlations between the ease of use of the application and the number of fixations. The aim of the latest study was to investigate how the application of UD principles affects the usability of online accommodation booking websites. The research was carried out using questionnaires and an eye tracker test. The results confirmed the positive impact of UD principles on the usability of these websites.

2.6. Related works on WAVE Tool

WAVE is a web accessibility assessment tool that, helps to detect and fix accessibility problems according to WCAG 2.1 guidelines. In [18] the aim of the study was to assess the level of usability and accessibility of four websites, two of the websites taking into account UD principles and two of them did not. The study was conducted using three independent surveys, an assessment of WCAG 2.1 compliance using the WAVE tool and an eye tracker. The results indicated that interfaces prepared according to UD allow people to find the information they need more quickly.

3. Research hypotheses

Before starting the research, a key aspect was to define the research hypotheses. As it was decided to place particular emphasis on readability, contrast and text size, as well as on meeting the principles of UD and WCAG 2.1, the following hypotheses were defined.

Due to the hypotheses developed, the study could be carried out in a more informed and precise manner. The hypotheses were divided according to the aspect they relate to. H1.1. and H1.2. focus on accessibility and usability, H2.1. deals with contrast. H3.1. and H.3.2. focus on readability based on text size.

- H1.1. Applications using WCAG 2.1 and UD guidelines provide higher accessibility and usability.
- H1.2. The users in applications applying the rules provided in WCAG 2.1 and UD need less time searching for elements on the page.
- H2.1. Webservices with poor contrast are more difficult to navigate between specific elements on the page.
- H3.1. Small font reduces time needed to find information on the page with poor contrast.
- H3.2. Small font reduces the time of finding elements on the page with proper contrast.

4. Materials and methods

The research methodology was a key part of the research, allowing data collection and analysis of the graphical user interfaces of music websites in terms of UD principles. Eye tracking technology, questionnaires and a WAVE tool were used to carry out the study. The research was divided into stages. The first was the creation of two music apps, one compliant with WCAG 2.1 and UD principles. The music services were created using TypeScript and the Angular framework. An eye tracking study was then conducted to collect data such as times to first fixation or the number of fixations needed for later analysis. The next step was for the respondents to complete the SUS (System Usability Scale) [19] and LUT (Lublin University of Technology Questionnaire) [20] questionnaires. The next step was to examine the developed applications using the WAVE tool [21]. The final step was to perform aggregation and analysis of the obtained results to verify the hypotheses.

4.1. Applications

As part of the research, we developed two applications, one compliant with WCAG 2.1 and UD principles and the other one that did not follow these rules.

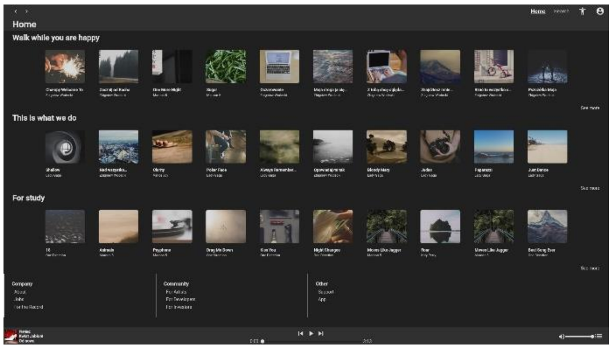

Figure 1: Dark mode, music categories page, first application.

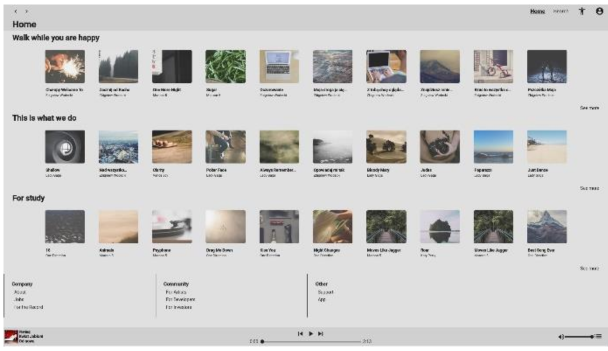

Figure 2: Light mode, music categories page, first application.

The first application was designed to provide users with the highest possible level of accessibility and usability (Figure 1). All interface elements were optimised for contrast (Figure 2) and readability especially taking into account the size of the text. Colours were selectively chosen to allow the application to be used independently of the user's level of vision. The structure of the application was designed to make the interface intuitive and as easy to use as possible, even for users with little computer experience.

Both applications were very similar. However, the second application (Figure 3) did not follow the principles of UD and WCAG 2.1, meaning that it contained neither interface elements that met the contrast requirements nor readability (Figure 4), and the structure of the application differed from generally applicable standards.

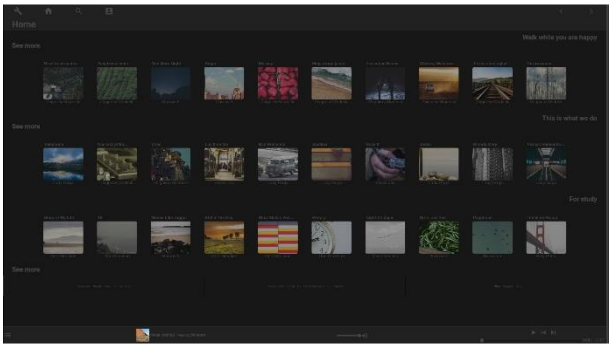

Figure 3: Dark mode, music categories page, second application.

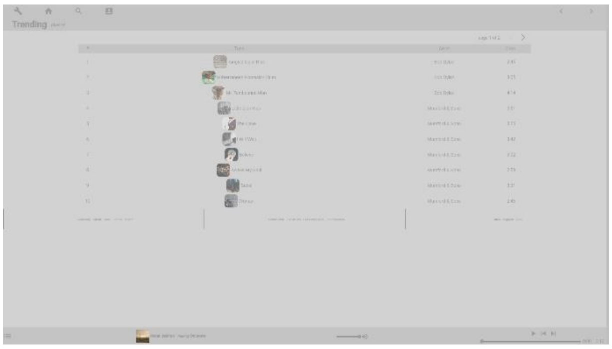

Figure 4: Light mode, trending category page, second application.

4.2. Participants

This study involved 21 participants (age 23-24) divided into two groups of 10 and 11 people. They all were IT students at the Lublin University of Technology, which means that they had a high level of knowledge related to computer technology. Their educational background may have influenced their level of understanding of the technical aspects of the tested applications. A prerequisite for the eye tracker test was the subject's prior unfamiliarity with the application.

4.3. Research stand

The research was carried out in the laboratories of the Department of Computer Science at the Lublin University of Technology. During the study, the best possible conditions were provided so that external factors did not affect the test results. The study involved one subject sitting in front of the computer (Figure 5) and one supervisor standing outside the eye tracker area.

The stand consisted of a Gazepoint GP3 HD eye tracker [22] connected to an Acer nitro 5 laptop equipped with an AMD Ryzen 75800H processor, 32GB RAM, NVIDIA GeForce RTX 3060 GPU, 512GB SSD, 15.6" screen with 1920x1080 resolution, Windows 11 operating system running Gazepoint Control and iMotions software to operate the eye tracker. The Gazepoint 3 HD eye tracker is characterised by its compact size and low weight, making it easy to carry. During the test, the eye tracker was placed between the computer monitor and keyboard to maximise comfort during the study. This eye tracker model features a high tracking accuracy for both eyes ranging from 0.5° to 1°. It is also possible to configure the frequency to be 60 or 150 Hz which can further increase the accuracy of the examination (during this study, the eye tracker was set to 150 Hz). The so-called bright pupil technique is used to collect data during the examination fixations, saccades, changes in pupil diameter, number of blinks, eyeball reaction times. The operation of the eye tracker was made possible by the Gazepoint Control program and had to be switched on during its operation. On the other hand, iMotions 9.0 software was used to conduct the test itself, calibrate the eye tracker and collect data. With this software, it was possible to display the tasks and application screens and then visualize the results in the form of paths, heat maps and tables of information.

Figure 5: Test stand consisting of an eye tracker, computer and mouse.

4.4. Eye tracker experiment

Prior to the start of the study, the study objectives and research scenarios were formulated. The design was prepared for both applications in iMotions software [23].

During the experiment, participants were assigned to various tasks that they were asked to perform, using a research stand with an eye tracker and a laptop. Each task was designed to collect data related to the participants gaze analysis and their reaction to different stimuli. At the end of the study, the data was recorded, and it was verified if the experiment was carried out correctly. The occurrence of problems during the test or the occurrence of low accuracy resulted in the discarding of the obtained result. The aim of the eye tracker test was to examine the participants reactions and behavior while performing the given tasks. As a results of the study, numerical data describing the correctness of the tasks performed (e.g. number of fixations) were obtained.

4.5. Research scenarios

Before starting the eye tracker study in iMotions software, a project was created based on the formulated research scenarios. Each individual experiment began with the creation of participants in iMotions software and research scenarios. In addition, an eye tracker configuration was required for each participant in order to obtain the best accuracy of the test. The following commands were displayed for the participants (Table 1) followed by the application screens. The participant had to look at a specific object on the screen and then, after locating it, press the spacebar and move on to the next task. Each subject had to complete 30 tasks 15 on a standards-compliant app and 15 tasks on an application that do not comply with UD and WCAG 2.1 principles. Each subject's task was displayed in a predetermined sequence in order to eliminate the risk of displaying two similar views in succession. The experiment was supervised by a competent person.

Table 1: Example of tasks during the test

No.	Task
1	Locate the author of the song named "18"
2	Locate the category named "Ambient"
3	Locate the length of the song named "Cleopatra"
4	Locate the link leading to the "For Artists" page
5	Locate the button that allows you to edit your account

4.6. Questionnaires

The eye tracker survey was followed by LUT and SUS questionnaires. This subsection describes how the questionnaires were conducted in the study. The most important aim of the questionnaires was to collect feedback from the respondents. The questionnaires allowed us to obtain respondents subjective opinions on the usability, functionality and readability of the two applications. Users took the surveys shortly after the eye tracker experiment.

During the preparation, it was decided to choose a questionnaire type SUS and LUT. The choice was then made to use a 5-point Likert scale in SUS type which is not the most precise, but which does not present the respondent with too many choices, which could have caused unnecessary confusion. After preparing the questionnaires, an important step was to test them to make sure the questions were clear and understandable to the respondents. After completing the individual eye tracker study, each participant was asked to fill out prepared questionnaires designed to gather their individual experience of the apps.

LUT questionnaire

LUT is a tool for assessing usability and satisfaction with the use of applications. The LUT is an off-the-shelf questionnaire tool, allowing the collection of feedback from users on their experience and satisfaction and easy comparability with other questionnaire using the LUT. This survey focuses on the subjective assessment of user satisfaction in the context of general aspects of the application. The questions in the LUT are formulated in such a way that the respondent can express his/her opinion using a 5-degree scale. The result is obtained by calculating the WUP (Web Usability Points) parameter:

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

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

SUS questionnaire

The System Usability Scale is one of the most popular tools for assessing the usability of systems. The questionnaire consists of 10 questions predefined for the questionnaire, of which five are negative and five are positive. Respondents rates various aspects of the system for this questionnaire on a 4-degree scale. The greatest advantages of this questionnaire are the comprehensible content, the speed of completion and the simplicity of the results obtained. Calculation of the results the sum of all ten questions and multiplying by 2.5 to obtain a scale from 0 to 100. The higher the numerical value, the better the overall usefulness of the system. After completing given tasks, participants were asked to fill out surveys electronically using google forms software. A survey supervisor was nearby at all times in case of any problems.

4.7. Wave study

In addition to the eye tracker tests and questionnaires, a study was carried out using the Wave tool. The Web Accessibility Evaluation Tool (WAVE) is one of the most popular tools for evaluating the accessibility of web applications. It was developed by WebAIM (Web Accessibility In Mind), an organisation that conducts research into web accessibility. Wave is a free tool that is available as a web service or browser plug-in. A web plug-in for the Google Chrome browser was used during this study. The main functions of the tool are detection of accessibility problems according to WCAG 2.1 guidelines, e.g. structural errors, contrast errors or alerts. Problems are visualised by generated reports (Figure 6).

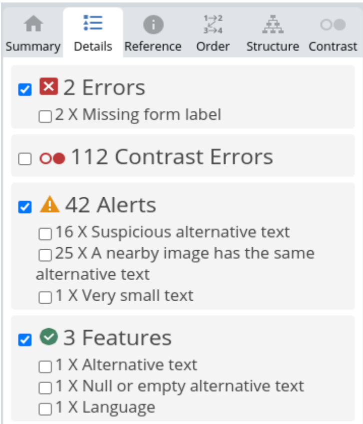

Figure 6: WAVE report.

The main use case for the WAVE evaluation tool is to automatically identify common errors in the area of accessibility and verify WCAG 2.1. This tool provides direct data on the above-mentioned elements. The resulting data are divided into corresponding categories, which facilitate subsequent analysis. Prior to the start of the study, three screens of a WCAG 2.1 and UD-compliant application and three screens of a non-compliant application were selected. The Wave tool was then installed on the computer in the browser. In the final step, the previously selected application screens were enabled and the Wave tool was activated. Once the study was completed, the data were saved for further analysis. By taking a broad approach to the research from multiple perspectives, as well as an objective and subjective approach, it provided valuable information on the impact of content accessibility on the quality of interfaces.

5. Results of studies

After the research was conducted, the results were analysed and then the research hypotheses were verified. The elaboration of the results was carried out using R Studio software.

5.1. Eye tracker results

Eye tracker study results confirmed that an app compliant with WCAG 2.1 and universal design principles had lower times to first fixation (Figure 7, Figure 9, Figure 10) and a lower average number of fixations (Figure 8). Figure 7 shows the distribution of mean times to first fixation represented by a box plot, where the extreme horizontal dashes on the box plot represent the minimum and maximum values, the walls of the box represent the Q1 and Q3 quartile, and the middle horizontal dash defines the median. Figure 9 shows a bar graph representing the average times to first fixation calculated for each task performed by the subjects. Figure 10 shows only those tasks that focused on examining the effect of text size on the times to first fixation of the performed tasks.

The average time to first fixation for an app applying WCAG 2.1 and UD rules is 1.3 s, and the average time to first fixation of an app not applying these requirements is 2.6 s. It can be observed that the time spent on the first app is on average twice as short as on the second one.

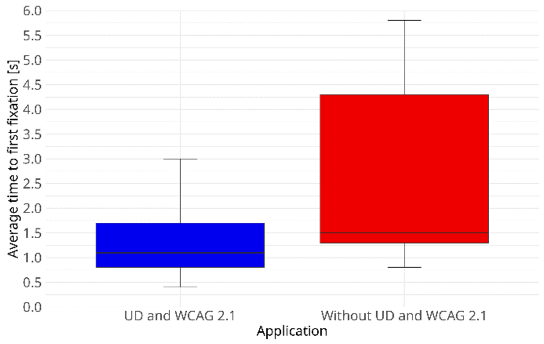

Figure 7: Distribution of average times to first fixation by application.

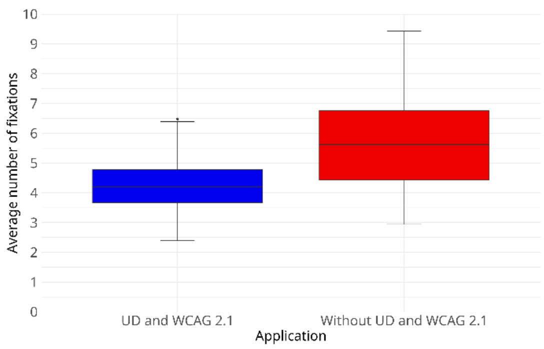

Figure 8: Distribution of average number of fixations by application.

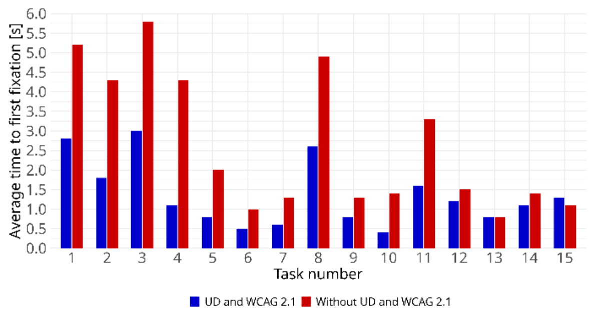

Figure 9: Average times to first fixation by task number by application.

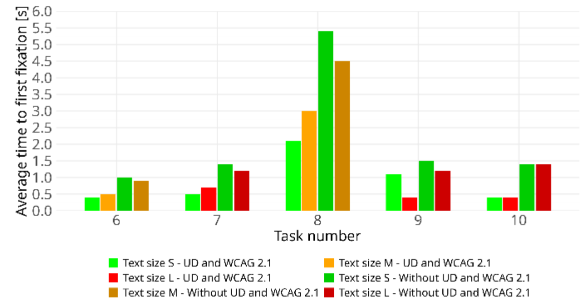

Figure 10: Average times to first fixation by text size.

5.2. Result of the LUT and SUS surveys

Through the LUT survey, WUP ratios were calculated (Figure 11). An application that was compliant with WCAG 2.1 and UD guidelines received a high WUP of 4.6 while a non-compliant application received a low score of 2.6. The first app received a 79% higher WUP score. As with the LUT survey, the SUS survey provided an opportunity to determine a more subjective SUS factor (Figure 12). Averaging the results, an application compliant with WCAG 2.1 and UD requirements received a high score of 90 points while a non-compliant one received only 34.25 points. This represents a 162.7% higher score in the case of the first application.

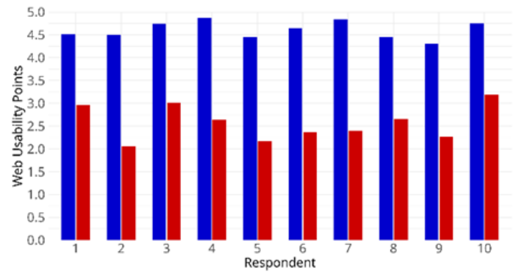

Figure 11: WUP factors for the LUT survey.

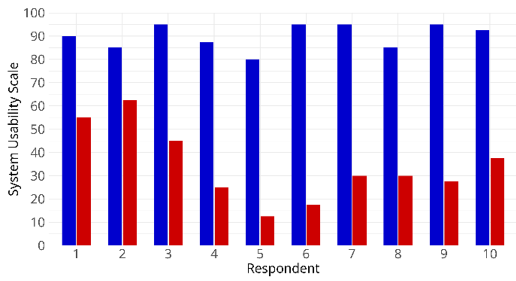

Figure 12: Results of the SUS survey.

5.3. Result of the Wave tool

The WAVE tool's report (Figure 13) showed a significant number of errors located on the side of the application that does not follow the WCAG 2.1 guidelines. For the compliant application, the WAVE tool did not show any errors.

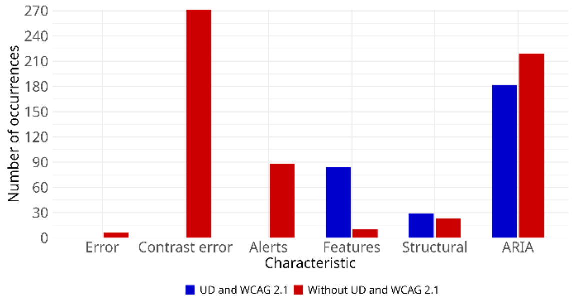

Figure 13: Number of occurrences by characteristic.

6. Conclusion

The conducted research made it possible to verify the postulated hypotheses. Smaller times to first fixation (Figure 7, Figure 9), smaller number of fixations (Figure 8) and high LUT and SUS survey results (Figure 11, Figure 12) for the application following WCAG 2.1 and UD guidelines allow to confirm hypothesis H1.1. The lower times to task shown in Figure 7 and Figure 9 confirm hypothesis H1.2. The application without applying the contrast guidelines outlined in WCAG 2.1 showed higher times to first fixation (Figure 7, Figure 9) which helped to confirm hypothesis H2.1. Higher times to first fixation for smaller text size for the application not following WCAG 2.1 and UD guidelines (Figure 10) confirmed hypothesis H3.1. The results of the study on text size did not clearly confirm hypothesis H3.2 this implies the need to formulate more detailed research in this area. In conclusion, the research confirmed that compliance with WCAG 2.1 and UD guidelines positively affects the usability and accessibility of applications. Further research should focus on a detailed analysis of the impact of individual factors on the use of applications and on determining the level of impact of each factor. In addition, extending the research to user groups such as the elderly or people with disabilities could provide more nuanced results.

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