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Katarzyna KUREK [*],
Maria SKUBLEWSKA-PASZKOWSKA [0000-0002-0760-7126]*,
Mariusz DZIENKOWSKI [0000-0002-1932-297X]*,
Paweł POWROZNIK [0000-0002-5705-4785]*

THE IMPACT OF APPLYING UNIVERSAL DESIGN PRINCIPLES ON THE USABILITY OF ONLINE ACCOMMODATION BOOKING WEBSITES

Abstract

One of the concepts of human-computer interaction is the usability of websites, consisting of features such as efficiency, satisfaction, memorability, and learnability. Usability is particularly important in the case of websites that the user is expected to learn on their own. The main aim of this study is to evaluate the usability of user interfaces of websites and, based on this, to find how this evaluation is affected by the application of universal design principles. The objects of the study are two websites, one complying with the principles of universal design - created for the purpose of the study, and the other – an existing commercial website operating in the market, which does not follow these principles. Three hypotheses are defined: 1) effectiveness and efficiency of analyzed websites are higher for a service that followed the principles of universal design than a website that did not comply with these rules; 2) the quality of the user interface is greater for the service fulfilling the principles of universal design; 3) the satisfaction with the interaction with the interface is greater in case of websites conformed to the principles of universal design. The study uses two methods: eye tracking and questionnaires. The experiment involves 10 participants who had to perform a scenario consisting of 10 instructions that involved locating various elements in each of the tested GUI interfaces. The eye activity is recorded using a Gazepoint GP3 HD desktop eye tracker, which makes it possible to determine the effectiveness and efficiency values of using the analyzed interfaces. Each participant was also asked to fill out two questionnaires: the Lublin University of Technology one and the Questionnaire for User Interaction Satisfaction. The study proves the truth of the hypotheses, that is, the positive impact of universal design on the usability evaluation of user interfaces.

[*] Lublin University of Technology, Faculty of Electrical Engineering and Computer Science, Department of Computer Science, Poland, maria.paszkowska@pollub.pl, m.dzienkowski@pollub.pl, p.powroznik@pollub.pl

1. INTRODUCTION

The usability is ever-present in human computer interaction. This term in relation to the Graphical User Interface (GUI) defines aspects describing the quality of using it (Nielsen, 1993). It can be represented by three attributes: efficiency, effectiveness and satisfaction, which refer to how the user achieves the intended goal under certain conditions (Abran et al., 2003). Usability analysis is a very important and necessary process related to the creation and development of GUI, because various problems on the page may be isolated, as well as the interface may be improved based on user feedback.

The perception of usability varies depending on different approaches, which influenced the creation of six images (aspects) of usability: universal usability, situational usability, perceived usability, hedonic usability, organizational usability, and cultural usability (Hertzum, 2010). They share a common concept but differ in perspective, scope and focus on collaborative or individual use. Due to this division, one can see how many issues are important to thoroughly understand the concept of usability. The universal usability is related to the desire to create a system that can be used by everyone. This aspect is extremely important in the walk-up-and-use systems such as ATMs, general-purpose systems (e.g., text processing), as well as web-based systems such as e-commerce, e-government, e-health, and e-learning (Hertzum, 2010). This brings to mind the definition of universal design which is the concept of creating products, software and environments to be usable by all people, to the greatest extent possible, without the need for adaptation or specialised design (Centre for Excellence in Universal Design, 2023). It includes accessibility, which describes how to create and design with the needs of people with disabilities in mind, so that they can use websites in the same way as other users (Web Design and Applications – Accessibility). The principles of universal design are: equality in use, flexibility in use, simplicity and intuitive operation, perception of information, error tolerance, low level of physical effort, size and space available for approach and use (Centre for Excellence in Universal Design, 2023).

Accessibility issues are described in the Web Content Accessibility Guidelines (W3C, 2023a). They contain guidelines on how web applications should be created so that they are compatible with universal design and thus meet the conditions of general accessibility. It is based on the principles of perceptibility, functionality, understandability and robustness which overlap with the principles of universal design (W3C, 2023b).

Despite many guidelines, standards and legislation, the needs of people with disabilities are still often overlooked and ignored for many reasons (Kreps, 2008). Research from WebAIM (2023) on a sample of 1,000,000 of the most popular websites showed that WCAG 2 errors were detected on 96.3% of the main pages of these websites. Low contrast was stated as the most common error (86.3%). This was followed by missing alternative text (58.2%), empty links (50.1%), missing labels for input data (45.9%), empty buttons (27.5%), and finally missing document language (18.6%).

The main aim of this study is to assess the usability of website interfaces for booking accommodation and then to verify how it is influenced by the application of universal design principles. Two websites were compared with each other: one that complies with the principles of universal design and the other that does not follow these principles. The analysis of the results obtained during the evaluation will help to examine the impact of this type of design on the usability level of the interface.

For the purpose of this study three hypotheses have been defined:

H1. The effectiveness and efficiency of analyzed websites were higher for a service that followed the principles of universal design than a website that did not comply with these rules.

H2. The quality of the user interface was greater for the service fulfilling the principles of universal design.

H3. The satisfaction with the interaction with the GUI was greater in case of websites conformed to the principles of universal design.

2. LITERATURE REVIEW

Using the ISO 9241 definition of usability (Abran et al., 2003), three attributes can be specified on the basis of which it can be assessed. The first one is performance, which is a metric that determines the number of resources used by the user to achieve the intended goal. In the case of studies on usability assessment, it is defined as the total and average time needed to complete the tasks set in the study. Effectiveness measures the completeness of a given task. It evaluates to what extent all the criteria necessary to achieve the goal have been met. The third attribute is satisfaction. It examines the user's perception of the service experience (Abran et al., 2003). In addition, another metric can be taken into account, which is the Web Usability Points (WUP) indicator, which is a subjective measure of the quality of the user interface. It is determined using the LUT survey (Miłosz, 2014).

There are many techniques for determining the usability assessment and its selected attributes. Their selection should take into account many factors such as time, cost, as well as the advantages and disadvantages of each of them (Liu, 2008). Eye-tracking tests involve observing the user while interacting with the interface under test.

In (Widyanti & Qurratu Ainizzamani, 2017) the usability study of transport service interfaces was described. The method of the think-aloud protocol with the use of an eye-tracker and the questionnaire method with the use of the Questionnaire for User Interaction Satisfaction (QUIS) questionnaire were used. Efficiency, effectiveness and satisfaction metrics were set. User interface issues were then identified based on the assessment. However, the experiment did not take into account the principles of universal design.

The eye-tracking method was also applied in (Chynał et al., 2018). It was used to perform user tests in order to assess the usability of the GUI of the e-commerce system. After collecting data, the areas of interest (AOI) were identified. Heat maps were analysed as well as eye-tracking metrics such as the number of fixations and the time to the first fixation. The study showed that the main problem affecting the assessment of usability was the wrong arrangement of GUI elements and their incorrect presentation. The effectiveness of the eye-tracking method in the usability study was confirmed.

The paper (Vollenwyder et al., 2022) explored the impact of accessibility on usability and user experience. Its significant impact was not noticed, however, when analysing user feelings about using the website, a positive impact of accessibility standards on their satisfaction was observed. There were significantly more positive feelings in the group of people with disabilities, and significantly fewer negative experiences in the group of able-bodied people. This contrasts with the study performed in (Schmutz et al., 2016). It was

carried out on a group of users without disabilities using websites with various levels of accessibility defined according to the Web Content Accessibility Guidelines (WCAG 2.0). The results showed an increase in performance (including time and completeness of task completion) and user interface ratings with increased availability. This confirmed the statement described in the article of (Cao & Loiacono-Mello, 2021) that accessibility was beneficial for all users. Similar studies were carried out in the works (Schmutz et al., 2017) and (Schmutz et al., 2018), which also confirmed the benefits of website accessibility for users without disabilities as well. The study of usability and accessibility in the context of the use of universal design principles was also described by (Badzio et al., 2022). The eye-tracking method and the LUT survey were used. Accessibility was tested using the WAVE tool. The analysis showed a positive effect of the use of principles on the tested webservices.

None of the abovementioned studies were applied to accommodation booking websites that are used by very diverse groups of people and should be equally accessible to all of them. This is important both for users who want to use the website quickly, effectively and with a sense of satisfaction, as well as for website owners - the more users, the greater their profit. Therefore, this study was undertaken to investigate this issue.

3. MATERIAL AND METHOD

3.1. Research participants

Ten participants took part in the research. Each of them was a computer science student at Lublin University of Technology, aged 23-24. They did not attend the universal design classes, so they were not experts in this field. Their experience in case of the use of webservices is comparable to an average Internet user and it results from the domination of everyday life by Internet applications.

3.2. Webservices

The existing Trip.com app was selected as the first webservice to the study. After inspecting it with the WAVE tool, it turned out that the site had numerous errors and did not follow the principles of the universal design. The main accessibility problems obtained were as follows: missing alternative text, missing labels, very low contrast and non-intuitive elements. For comparison, using React, Next.js and the MUI component library, a second website was created, taking into account the principles of universal design. It was designed like the Trip.com website – it had the same functionalities but differed in the arrangement, contrast and appearance of interface elements. The developed website was also verified with the WAVE tool, but no errors were obtained.

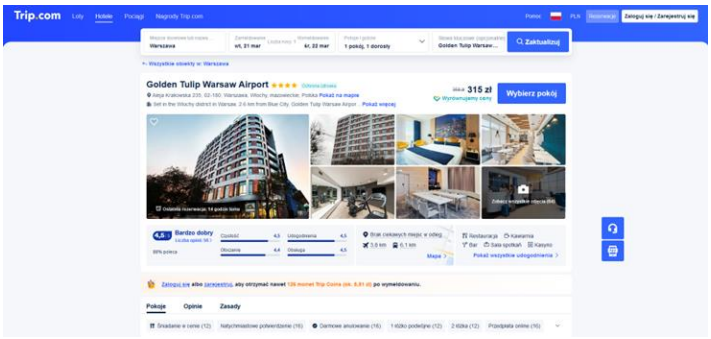

Fig. 1. Screen of an application that breaks the rules of universal design

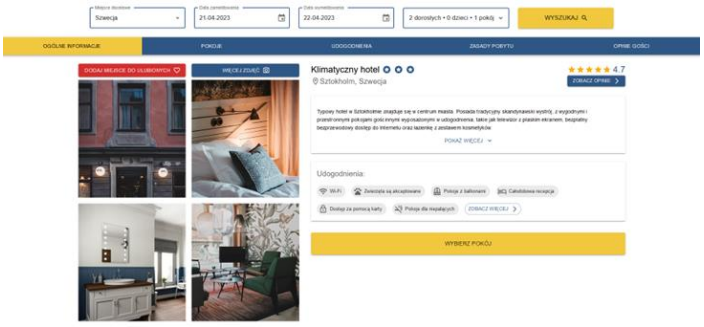

Fig. 2. Screen of an application compliant with the principles of universal design

3.3. Research stand

The experiment was carried out in a laboratory of the Department of Computer Science at Lublin University of Technology. Appropriate lighting conditions for conducting the study were provided in the room. Each of the participants sat on an adjustable chair, ensuring the correct position during the examination. Each of the conducted research sessions was attended by a supervisor who explained the details of the research to the participants and monitored the accomplishment of the tests.

The experiment was carried out using the Gazepoint GP3 HD eye tracker connected to the Acer Nitro 5 AN517-41-R48Y laptop with the following parameters:

- processor: AMD Ryzen 7 5800H (8 x 3.2GHz);
- 32GB DDR3 memory;
- Nvidia Geforce RTX 3060 6GB graphics card;
- 512GB SSD;
- 17.3” screen with a resolution of 1920x1080;
- Windows 10 x64 Education.

The eye tracker specification was as follows:

- sampling frequency: 60Hz;
- calibration: 9-points;

- detection of fixations, saccades and changes of eye pupil;
- accuracy: 0.5-1°.

iMotions 9.0 software was used to perform the experiment. This program allowed to record sessions of users participating in the experiment and visualize the results in the form of: scanning paths, heat maps and attention maps. iMotions also allowed to generate statistics based on area of interest and export data.

3.4. Eye-tracking study

Two experiments were carried out to assess the usability of selected websites. Each of them was based on prepared scenarios – one of the them used a website that complied with the principles of universal design, the other one did not follow them. The eye tracker study involved the user performing successive tasks according to a scenario. The user was prompted to locate the selected GUI element (Table 1). The time to complete the task was limited to 8s. After this time, the task was considered to be failed. The first experiment was carried out for the screens of website that did not follow the principles of universal design, and then for the views of one that respected the given rules. Areas of interest (AOI) were defined for each screen of the application. They were used to determine the metrics necessary to assess the usability of the interface: the time to first fixation (TTF) and the number of respondents who focused on the AOI in a given time. The collected data were used to determine the effectiveness and efficiency of the analyzed webservices.

Tab. 1. Set of tasks

Task no.	Task
1	Locate the amenities section
2	Locate the filter - type of facility "Hotel"
3	Locate the check-in and check-out dates
4	Locate the field that allows you to enter your destination
5	Locate the item that allows you to add a place to your list of favourites
6	Locate the “WiFi” type of amenities
7	Locate the e-mail address input field
8	Locate an item to see more sorting options
9	Locate the “Rooms” tab
10	Locate the date the review was posted

3.5. Evaluation surveys

After the test, each user received two surveys: LUT and QUIS. The LUT survey consisted of 32 questions, which were grouped into areas and subareas related to various aspects of the interface (Miłosz, 2014). The LUT survey is presented in Table 2. Answers were given using a 5-point scale. On their basis, the designated WUP (Web Usability Points) indicator was calculated, which determined the subjective measure of the quality of the interface. The QUIS was used to subjectively assess user satisfaction when interacting with an interface (Chin et al., 1988). Its shortened version 5.0 consisted of 27 questions with a rating scale from 0 to 9 (Table 3). It assessed the overall feeling related to the interaction as well as to individual areas.

Tab. 2. LUT survey (Miłosz, 2014)

Area	Subarea	Question
Navigation and structure	Ease of navigation	Is it easy and intuitive to access all sections of the application?
		Is it easy and intuitive to access all functionalities of the application?
	Information hierarchy	Is the information hierarchy too deep?
	Information structure	Is the information structure thoughtful?
		Is the information structure consistent?
		Is the information structure understandable to the user?
	Screen elements	Do the screen elements support the navigation process?
Messages, feedback and user help	Messages (general)	Do the messages provide enough feedback on the status of user operations?
	Error messages	Do the error messages contain tips on how to solve the problem?
	Feedback and help	Do the feedback and help appear in places where they may be needed?
		Is the help content accessible to the average user?
		Is the help content understandable to the average user?
		Are the presented tips or solutions to problems possible to implement by an average user?
Application interface	Layout	Is the layout readable?
		Is the layout adaptable to different resolutions?
		Is the layout adapted to mobile devices?
		Is the graphic layout consistent?
		Does the layout support the implementation of tasks?
	Color selection	Is the contrast between text and background appropriate?
		Does the selection of colors enable the application to be used by people with color vision disorders?
		Does the selection of colors enable the application to be used on various types of displays?
Content of subpages	Texts	Are texts understandable to the user?
	Nomenclature	Is the nomenclature used in the application consistent?
		Is the nomenclature used in the application understandable?
	Labels	Do the labels used in the interface provide enough information?
		Do the interface elements have the necessary labels?
Data input	Forms	Do the forms have a clear design?
		Do the forms allow you to enter the necessary data?
		Are the forms mobile-friendly?
	Data	Does the average user have difficulty with entering data into the form?
		Do the forms have any hints regarding the entered data (e.g. format, scope)?
		Do the forms have elements validating the entered data?

Tab. 3. QUIS survey (Chin et al., 1988)

Overall reaction to the software		**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	
1	terrible											wonderful
2	difficult											easy
3	frustrating											satisfying
4	inadequate power											adequate power
5	dull											stimulating
6	rigid											flexible
Screen		**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	
Reading characters on the screen	hard											easy
Highlighting simplifies task	not at all											very much
Organization of information	confusing											very clear
Sequence of screens	confusing											very clear
Terminology and system information		**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	
Use of terms throughout system	inconsistent											consistent
Terminology related to task	never											always
Position of messages on screen	inconsistent											consistent
Prompts for input	confusing											clear
Computer informs about its progress	never											always
Error message	unhelpful											helpful
Learning		**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	
Learning to operate the system	difficult											easy
Exploring new features by trial and error	difficult											easy
Remembering names and use of command	difficult											easy
Performing tasks is straightforward	never											always
Help messages on the screen	unhelpful											helpful
Supplemental reference material	confusing											clear
System capabilities		**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	
System speed	too low											fast enough
System reliability	unreliable											reliable
System tends to be	noisy											quiet
Correcting your mistakes	difficult											easy
Designed for all levels of users	never											always

4. RESULTS

4.1. Eye tracking

The first metric analysed was the time to first fixation (TTFF). This was the average time that the user needed to locate the indicated element, which was defined as an area of interest. It reflected efficiency, i.e. the time needed to complete the task. A longer time meant that users had more trouble finding the element, which might be due to its poor visibility or bad position. A shorter time, on the other hand, indicated that the element was much better visible and located. The results for the conducted experiments are presented in Table 4. In Fig. 3. their graphical representation in the form of a box plot is shown.

Tab. 4. Average TTFF inside the AOI

	No-UD website (ms)	**UD website (ms)**
Screen 1	3128.11	1328.23
Screen 2	2146.51	970.01
Screen 3	1365.25	1621.97
Screen 4	1016.30	759.62
Screen 5	2620.83	1600.24
Screen 6	2169.32	1114.45
Screen 7	987.48	796.21
Screen 8	3666.08	1370.79
Screen 9	2556.98	1250.95
Screen 10	2078.25	653.91
Mean	2173.51	1146.63
Variance	766119.80	119265.90
Standard deviation	875.28	345.34
Confidence intervals	711.96	288.37
Shapiro-Wilk test	0.67	0.55

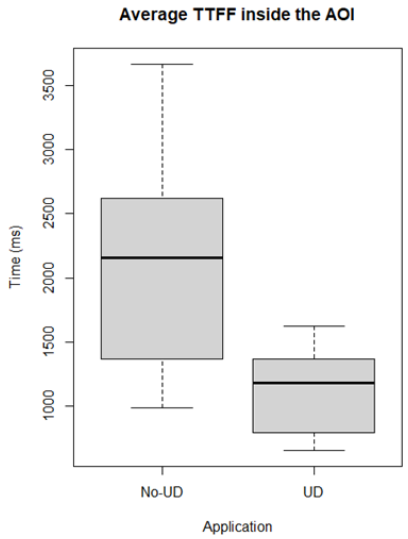

Fig. 3. Average TTFF inside the AOI – box plot

Another analysed metric was the percentage of respondents who focused on AOI, which was tantamount to finding the element they were looking for and thus completing the task. It reflected effectiveness, one of the searched usability assessment parameters. The results are presented in Table 5 and in Fig. 4.

Tab. 5. Percentage of respondents that gazed at the AOI

	No-UD website (%)	**UD website (%)**
Screen 1	30	70
Screen 2	80	100
Screen 3	100	100
Screen 4	100	100
Screen 5	50	70
Screen 6	40	100
Screen 7	80	100
Screen 8	30	90
Screen 9	70	80
Screen 10	90	90
Mean	67	90
Variance	756.66	155.55
Standard deviation	27.50	12.47
Confidence intervals	19.67	8.92
Shapiro-Wilk test	0.10	0.14

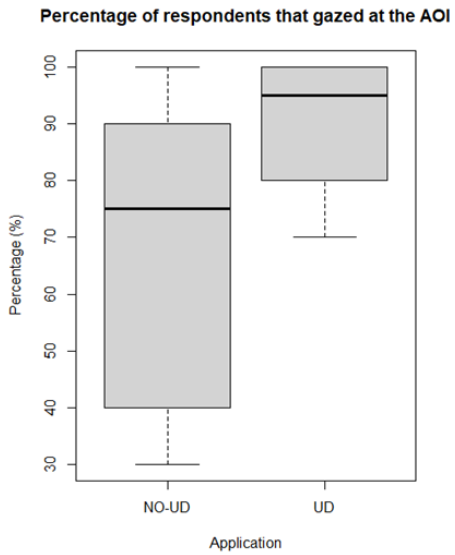

Fig. 4. Percentage of respondents that gazed at the AOI – box plot

In addition, heat maps were taken into account in the analysis process. Their examples are visible in Fig. 5 and Fig. 6. They show to what extent user attention was focused on particular elements of the interface. They contain the collective results of all study

participants for individual tasks. The more red areas appear, the greater the interest is. Colours ranging from orange, through yellow and green are areas that attract less and less attention.

Fig. 5. A heat map of an application that violates the rules of universal design

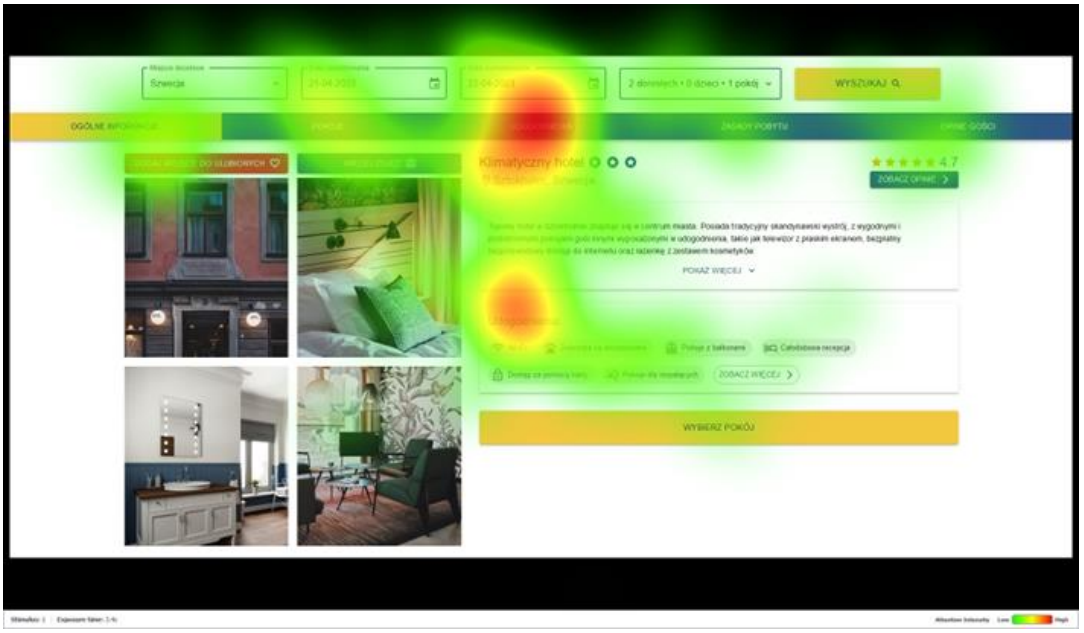

Fig. 6. A heat map of an application in accordance with the principles of universal design

In Fig. 7 and Fig. 8 the scanning paths are visible. Unlike heat maps, these are individual scores, not collective scores. The paths represent the path followed by the participant's eyes, with marked circles and numbers denoting subsequent fixations. The searched item is marked with a red frame.

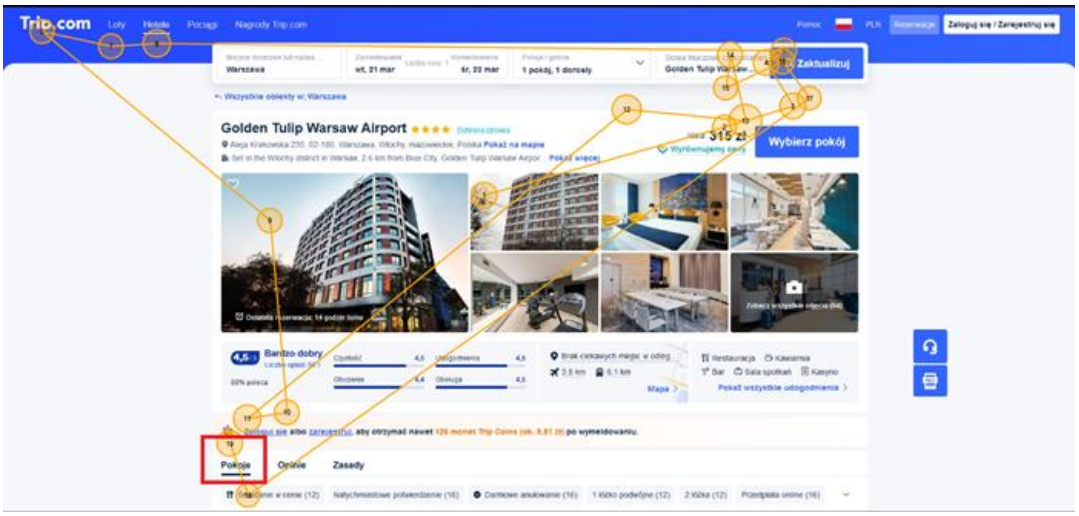

Fig. 7. Scan paths of an application that violate the rules of universal design

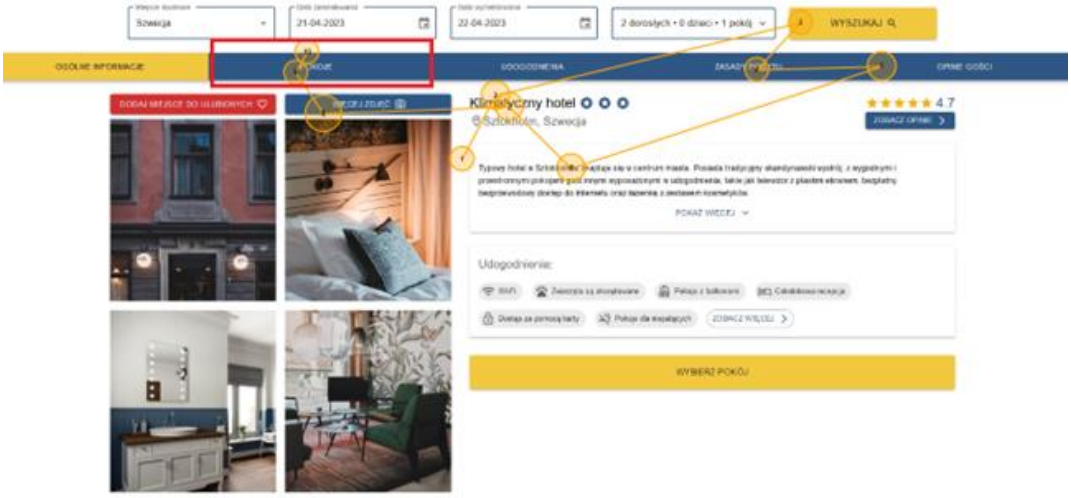

Fig. 8. Scan paths of an application in accordance with the principles of universal design

4.2. Evaluation surveys

Based on the answers collected from the LUT survey, the WUP indicator was determined. The results are presented in Table 6 and in Fig. 9.

Tab. 6. LUT survey results

	WUP score of the NO-UD website	WUP score of the UD website
Participant 1	4.37	4.95
Participant 2	3.41	4.81
Participant 3	3.30	4.52
Participant 4	1.63	4.93
Participant 5	2.27	4.68
Participant 6	4.53	5.00
Participant 7	4.05	4.23
Participant 8	4.90	4.75
Participant 9	4.71	4.47
Participant 10	4.59	3.94
Mean	3.77	4.62
Variance	1.22	0.12
Standard deviation	1.11	0.34
Shapiro-Wilk test	0.11	0.33

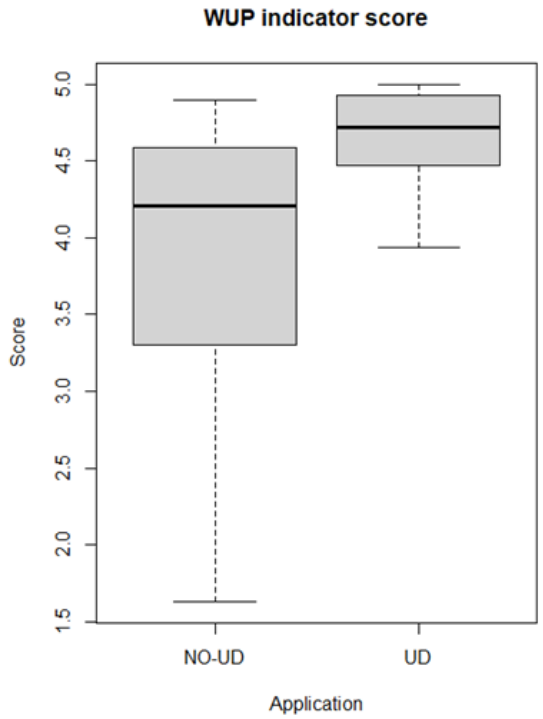

Fig. 9. LUT survey results – box plot

For the next QUIS survey, the average of all responses was determined. The results are presented in Table 7 and in Fig. 10.

Tab. 7. QUIS survey results

	QUIS score of the NO-UD website	QUIS score of the UD website
Participant 1	4.52	7.52
Participant 2	5.15	8.15
Participant 3	4.59	6.81
Participant 4	1.67	8.70
Participant 5	3.19	8.15
Participant 6	6.44	7.74
Participant 7	6.52	7.52
Participant 8	8.33	8.56
Participant 9	6.78	8.46
Participant 10	6.59	6.48
Mean	5.38	7.81
Variance	3.84	0.55
Standard deviation	1.96	0.74
Shapiro-Wilk test	0.69	0.43

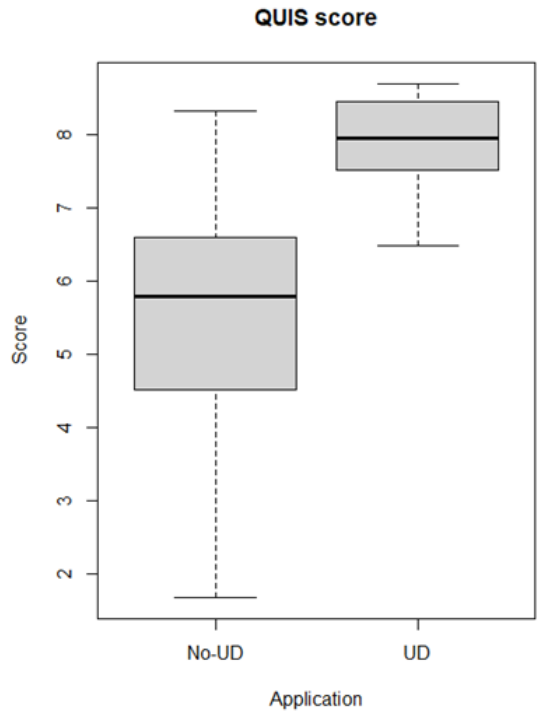

Fig. 10. QUIS survey results – box plot

5. DISCUSSION AND CONCLUSION

The aim of this study was to examine the impact of applying universal design principles on the usability of user interfaces for booking accommodation webservices. Three research hypotheses were defined. The first of them (H1) refers to the efficiency and effectiveness of using the website. The data collected from the eye-tracker tests were used to resolve it. In the case of efficiency, the time to the first fixation was analysed. For the webservice compliant with the Universal Design the average TTFF reached 1146.63 ms and for a non-compliant webservice - 2173.51 ms, which was almost double the time. This means that performance was better for a software that followed the principles of universal design. During the effectiveness analysis, the percentage of participants who completed the task within the prescribed time, i.e. found the element they were looking for by focusing their attention on the area of interest, was taken into account. The average percentage for a compliant webservice was 67 and for a non-compliant page 90. Again, there is a significant difference for both sides. This difference was confirmed by the analysis of heat maps and scanning paths. In heatmaps generated for an application that did not adhere to the principles of universal design, there were more areas of eye focus of study participants, which means more distraction while performing tasks. In the case of scan paths, there was a noticeable difference in their length. For an application that complied with the rules, the path that the user's eyes had to travel to find the searched item was usually shorter than in the case of the other service.

The results of the LUT survey, and more precisely the values of the WUP indicator, confirm the statement in the second hypothesis (H2). According to the research participants, the quality of the interface was higher in the case of a site that complies with the principles of universal design than in the case of a website that did not adhere to these principles. The same was true for user satisfaction and hypothesis H3. It should be noticed that the LUT survey is a subjective measure. Participants assessed the webservices based on their own preferences. In Table 6, it can be seen a large variety of ratings for a website that does not support the principles of the universal design. Three persons assessed it higher than the website developed in accordance with the principles of universal design. However, only in the case of one participant assessments are significantly different. The remaining two rated them at the same level of satisfaction. Although the participants' experience in case of use of webservices is comparable to an average Internet user and it results from the domination of everyday life by Internet applications, it would be worth extending the study on other groups of participants, taking into consideration their age, computer skills, or visual diseases.

The obtained results are consistent with those reported in the analysed literature (Badzio et al., 2022, Schmutz et al., 2016), as well as in the study by (Vollenwyder et al., 2022) in terms of user satisfaction results. The study finally confirmed the truth of the hypotheses, i.e. the positive impact of universal design on the usability of user interfaces. The presented study in this paper has shown the importance of applying Universal Design principles to everyday applications. This makes activities significantly faster and easier for users. As only two websites were taken into consideration, these studies can be extended to a larger number of websites in the future. In order to obtain more accurate results, more participants and a group of people with visual impairments can be involved.

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