JOURNAL of COMPUTER SCIENCES INSTITUTE

JCSI 25 (2022) 315–322
Received: 17 June 2022
Accepted: 4 July 2022

Analysis of the graphical user interface of the online store, taking into account the methods of universal design
Analiza graficznego interfejsu użytkownika sklepu internetowego z uwzględnieniem metod projektowania uniwersalnego

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Abstract

Universal design is a philosophy of creating various products and the environment to adapt to the most comprehensive possible group of recipients. This article aims to compare interfaces with the principles of universal design and application interfaces that ignore such principles. After the literature review, the following research hypotheses were posed: "Higher interface contrast affects the visibility and speed of searching for individual elements of user interface" and "The arrangement of interface elements has a significant impact on navigating the website". The research was conducted on two websites. The Empik storefront was a webservice that did not comply with universal design principles. The application that follow the regulations of universal design was created for the purpose of research. Three methods of measuring the quality of interfaces were used in the study: WAVE tool, eye-tracking tests, and subjective assessment using the LUT questionnaire (Lublin University of Technology). Eye tracking study showed that participants needed an average of 2 times less time to locate elements on a high-contrast interface and 4 times less time to locate all components placed compliant with generally accepted design standards.

Keywords: universal design; contrast; arrangement of graphic elements; interface

Streszczenie

Projektowanie uniwersalne jest filozofią tworzenia różnych produktów oraz otoczenia tak, aby było ono dostosowane do jak najszerszego grona odbiorców. Celem niniejszego artykułu jest porównanie interfejsów z uwzględnieniem zasad projektowania uniwersalnego oraz interfejsów aplikacji, które pomijają takie zasady. Po zapoznaniu się z przeglądem literatury postawione zostały następujące hipotezy badawcze: „Większy kontrast interfejsu ma wpływ na widoczność oraz szybkość wyszukiwania poszczególnych elementów interfejsu graficznego" oraz „Rozmieszczenie elementów interfejsu ma zasadniczy wpływ na efektywność poruszania się po serwisie". Badania przeprowadzone zostały na dwóch serwisach internetowych. Serwisem niespełniającym zasad projektowania uniwersalnego była witryna sklepu Empik. Zaś aplikacja spełniająca zasady projektowania uniwersalnego została stworzona na potrzeby badań. W pracy zastosowano trzy metody pomiaru jakości interfejsów: narzędzie WAVE, badania okulograficzne oraz badania subiektywnej oceny za pomocą ankiety LUT. Badania okulograficzne wykazały, że uczestnicy badania potrzebowali średnio 2 razy mniej czasu na zlokalizowanie elementów na stronie o wysokim kontraście oraz 4 razy mniej czasu na znalezienie wszystkich komponentów umieszczonych w miejscach zgodnych z ogólnie przyjętymi normami projektowania.

Słowa kluczowe: projektowanie uniwersalne; kontrast; rozmieszczenie elementów graficznych; interfejs

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1. Introduction

The universal design is a philosophy of creating various products and the environment to adapt to the most comprehensive possible group of recipients [11]. It cannot be expected that everyone's requirements and needs will be fulfilled. You can only try to extend the group of users through various facilities. The most common problems of the interfaces of websites are the size, color and arrangement of elements, which makes it difficult for people with visual impairments to locate the things they need.

Hundreds of thousands customers are visiting the online stores every day. It is therefore important that the websites provide the most important principles of universal design, such as: equitable use, flexibility in use, simple and intuitive, perceptible information, tolerance for error, low physical effort, size and space for approach and use. Most people entering the website expect a search engine and a login form in the upper part, so they direct their eyes there first. An important element is also the ability to change the contrast and the ability to enlarge the elements of the graphical user interface (GUI) and the font. It is much easier to find an object of interest on a high contrast page.

The purpose of this article is to analyze the comparison of interfaces, taking into account the principles of universal design and application interfaces that ignore such principles. The analysis refers to three methods of study: subjective assessment carried out using the LUT survey, assessment of the Web Content Accessibility Guidelines (WCAG) 2.0 rules using the WAVE tool and an eye-tracking test, during which the time to locate individual elements of the graphical interface was measured. The following study hypotheses were defined: “Higher interface contrast affects the visibility and speed of searching for individual elements of user interface” and “The arrangement of interface elements has a significant impact on navigating the website”.

2. Literature review

The article [1] presents study assessing the impact of the choice of development technology on the quality of website accessibility. The authors focused in particular on programming languages, Web and JavaScript frameworks and content management systems. Their availability was automatically assessed using QualWeb and Wapplayzer. Comparing Internet frameworks, the study indicated lower availability of websites using Microsoft ASP.NET technology com-pared to Ruby on Rails and Twitter Bootstrap.

The purpose of the study presented in publication [2] was to examine the Web Accessibility Initiative (WAI) guidelines on web accessibility in order to integrate it into the IT systems teaching program. The authors used the WebXact Accessibility Assessment Tool to test the best website pages from 23 California State University campuses to determine the level of compliance with federal standards. The results of the study showed that most of the pages tested did not fulfill the WAI guidelines.

The study presented in article [3] consisted in examining the availability of websites. Received the answer for the questions such as: why the topic of accessibility is so rare and what can be done to solve this problem from the perspective of students and lecturers were obtained. For this purpose, a survey among students was conducted. The study results showed that most of the participants were unfamiliar with any WAI guidelines. Conversely, with the knowledge of the WCAG, the majority were familiar with these guidelines.

The purpose of the study presented in publication [4] was to verify pages for compliance with availability. The authors of the article used the home pages of Kentucky academic libraries for this purpose which were tested using WebXACT and Semantic Data Extractor. The results of the study showed that only one institution created an extensive outline based on the use of the headline. The home pages of only two libraries had at least one access key on their home page.

The authors of the article [5] described the guidelines for accessibility such as proper screen size or font sizes together with the most effective practices for creating websites. The purpose of the work was to develop a tool and logic to verify the accessibility of websites, and then to examine professionally designed interfaces. Then, the developed tool was used to test 62 professional websites. During the study, 64 significant availability errors were found.

The purpose of the article [6] was to analyze software for automatic website validation according to WCAG 2.0 guidelines. The Moodle platform was used for this purpose during the evaluation. In the article, the authors assessed the selected tool and compared the testable WAVE errors with the WCAG 2.0 guidelines. It was found that WAVE performed well despite the lack of several WCAG 2.0 guidelines and that the tool is more suitable for developers than for general users.

The authors [7] review in their article the techniques for using the Web to read the screen. The review covered techniques for removing excessive content, handling online transactions, interacting with speech, and automating assistants. All of these techniques used non-semantic knowledge of web content to improve web usability. This review showed that understanding web content semantics is the overarching topic that drives web usability techniques.

During the study [8], the websites of the best universities were tested for accessibility using WCAG 2.0. The individual pages were assessed using HERA, Test de accessibilidad Web (TAW) and the Firefox Accessibility Evaluation Toolbar. Result of study showed that most educational sites follow less than 50% of the guidelines.

According to the knowledge of the authors of the analyzed publications, the study on the search time for elements on given pages with low and high contrast and elements located in places compliant and inconsistent with the generally accepted principles of universal design has not been performed.

3. Study methods

Three methods of measuring the quality of GUI were used in this study: WAVE tool, eye tracking tests and LUT questionnaire.

Individual stages of the study were as follow:
1. Defining the study issues, aim and study hypotheses.
2. Selection of websites under study.
3. Creating an online store application to carry out the study.
4. Development of study scenarios.
5. Design of experiments.
6. Conduct and registration of study.
7. Processing of collected data and analyzing them.
8. Evaluation of the results and conclusions.

3.1. Study object

The study was conducted on two websites. The site that did not fulfill the principles of universal design was Empik [9]. The page [10], which complies with the principles of universal design, was created for the purpose of this study. It is an online store that allowed you to register a user, log in (Figure 1) and purchase products. You can also change the contrast, resize text and interface elements and underline hyperlinks.

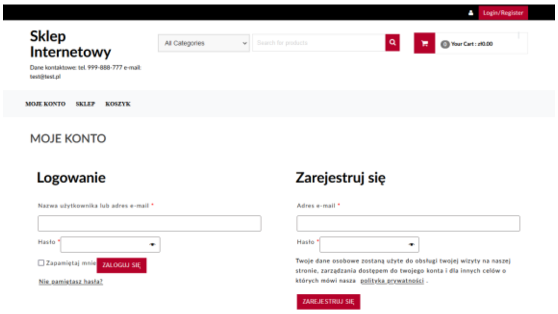

Figure 1: The "my account" subpage that allows you to log in and register.

3.2. Study group

Twenty IT students of the Lublin University of Technology with extensive experience in navigating websites participated in the study. Each of these people participated in the eye tracking study and half of them completed the LUT questionnaire.

3.3. WAVE Tool

In the first part of the experiment, the WAVE (Web Accessibility Evaluation Tool) validator was used [12]. This method enables quick and automatic examination of the website in terms of the availability of the WCAG 2.0 standard. This tool identifies site errors in 3 categories: contrast errors, page element structure and ARIA.

3.4. Eye tracking study

Then, an eye tracker study was conducted on Gazepoint GP3 HD [13] using 4 scenarios consisting of two different sets of commands.

The first set was conducted for searching elements on a low and high contrast page. The set contained the following commands:

1. Please locate the product search engine.
2. Please locate the product named "Billy Summers".
3. Please locate your shopping cart.
4. Please locate the "go to payment" button.
5. Please locate the field for entering discount coupons.
6. Please locate the "login" button.
7. Please locate "forgot password".
8. Please locate the total order value.
9. Please locate the "privacy policy".
10. Please locate the button "buy and pay".

The second set's purpose was to examine the search time for page elements located in places compatible and incompatible with generally accepted universal design principles for this type of pages and it contained the following commands:

1. Please locate the Product Finder.
2. Please locate the button that will take you to the login page.
3. Please locate your shopping cart.
4. Please locate social media.
5. Please locate the category change list.
6. Please locate the contact details.
7. Please locate the button leading to the top of the page.
8. Please locate the button that opens the accessibility menu.
9. Please locate the "send" button.
10. Please locate the "register" button.

When analyzing the data collected after the study, particular attention was paid to the time needed to complete a given task and the number of incorrectly completed tasks.

3.5. LUT Survey

The final stage of the experiment was to conduct a subjective assessment by means of the LUT questionnaire [14] among the participants of the study.

The survey was divided into 5 areas and 13 subareas. The questions can be rated on a scale from 1 to 5, where 1 was the worst and 5 was the best. Each participant was to complete the questionnaire after checking out the site, based on the following scenario:

1. The user enters the home page.
2. The user selects the element that allows to go to the "my account" subpage.
3. The user registers on the website.
4. The user logs in to his account.
5. The user goes to the store subpage.
6. The user changes the contrast.
7. The user increases the text size.
8. The user selects one of the products by going to its description.
9. The user adds 2 items of the product to the cart.
10. The user goes to the shopping cart.

The final rating of the examined website is the WUP (Web Usability Points) [14] indicator, the value of which ranges from 1 to 5, where 1 was the worst and 5 was the best.

4. Results

The static analysis was performed using the car library, minqa and carData packages and a tool created in the R language. In order to verify whether the distribution of the samples was similar to the normal distribution, the Shapiro-Wilk test was performed. Additionally, Levene's test and Student's t-test were performed to verify if the data were significantly different.

4.1. Eye tracking study – Time To First Fixation (TTFF)

Table 1 shows the times to the first fixation collected during the study on the impact of the interface layout on the search speed. Given data (table 1) relates to elements compatible (UD-enabled) and incompatible (No-UD) with generally accepted universal design principles.

Table 1: TTFF to locate an element relative to its arrangement

	UD-enabled website Time (ms)	No-UD website Time (ms)
Screen 1	815.6	2535.6
Screen 2	793.8	2330.9
Screen 3	272.1	1545.2
Screen 4	612.5	2295.7

Screen 5	832.1	2123.1
Screen 6	487.3	2249.4
Screen 7	753.2	3164.8
Screen 8	1299.1	4,622.7
Screen 9	617.7	3662.1
Screen 10	459.0	3595.8
Mean	694.24	2812.53
Variance	77986.85	856712.89
Std. Dev.	279.26	925.58
Conf. Int.	199.77	662.12
Shapiro-Wilk	0.93	0.93
Test Levene	5.01	
T-test	$1.78 * 10^{-6}$	

Table 2 shows the times to the first fixation of locating the element, collected during the tests, in which the influence of GUI contrast was taken into account. The speed of searching for elements in terms of low and high contrast was tested.

Table 2: TTFF to locate the element in terms of contrast

	UD-enabled website Time (ms)	No-UD website Time (ms)
Screen 1	683.4	2796.5
Screen 2	384.3	1444.9
Screen 3	356.5	2926.8
Screen 4	565.3	2132.7
Screen 5	924.2	1320
Screen 6	785.9	1523.4
Screen 7	437.7	1623.1
Screen 8	520.4	3632.2
Screen 9	594.3	3749.4
Screen 10	317.3	2707
Mean	38635.76	820907.72
Variance	556.93	2385.60
Std. Dev.	196.56	906.04
Conf. Int.	140.61	648.14
Shapiro-Wilk	0.95	0.91
Test Levene	23.62	
T-test	$6.96 * 10^{-6}$	

4.2. Eye tracking study – fixation number

Tables 3 – 5 present the study results of the fixations number for the page elements searching, which are placed in accordance with the generally accepted principles of universal design and for elements that do not fulfill these rules. The greater the number of fixations mean, the longer the user analyzed the page. This element determines whether the page is properly designed.

Table 3: The number of fixations for the study of the search time of page elements located in places compliant with the generally accepted principles of universal design

Scr.	UD-enabled website				
	Mean	Std. Dev.	Variance	Conf. Int.	Shapiro-Wilk
1	6.25	7.07	50.09	3.31	0.58
2	7.5	7.89	62.26	3.69	0.66
3	5.25	3.12	9.77	1.46	0.91
4	6.85	4.39	19.29	2.05	0.82
5	7.75	5.41	29.35	2.53	0.85
6	5.6	3.47	12.04	1.62	0.77
7	5.4	4.51	20.35	2.11	0.74
8	7	5.16	26.63	2.41	0.79
9	4.75	2.57	6.61	1.21	0.83
10	4.6	2.81	7.93	1.31	0.91

Table 4: The number of fixations for the study of the search time of page elements located in places inconsistent with the generally accepted principles of universal design

Scr.	No-UD website				
	Mean	Std. Dev.	Variance	Conf. Int.	Shapiro-Wilk
1	15.6	9.08	82.56	4.25	0.79
2	38.5	23.86	569.53	11.16	0.91
3	16.2	10.37	107.64	4.85	0.91
4	18.3	10,41	108.32	4.87	0.91
5	32.15	20.36	414.66	9.53	0.86
6	17.45	9.65	93.21	4.51	0.94
7	15.6	9.85	97,20	4.61	0.91
8	15	10.67	113.89	4.99	0.91
9	14.1	8.43	71,14	3.94	0.91
10	15.35	9.92	98,45	4.64	0.81

Table 5: Levene's test and t-test for pages with different arrangement of elements

	Test Levene's	T-test
Screen 1	0.76	$8.31 * 10^{-4}$
Screen 2	0.36	$2.63 * 10^{-6}$
Screen 3	0.18	$5.89 * 10^{-5}$
Screen 4	0.51	$5.65 * 10^{-5}$
Screen 5	0.56	$7.59 * 10^{-6}$
Screen 6	0.01	$7.91 * 10^{-6}$
Screen 7	0.14	$1.52 * 10^{-4}$
Screen 8	0.27	$4.52 * 10^{-3}$
Screen 9	0.02	$2.97 * 10^{-5}$
Screen 10	0.56	$3.81 * 10^{-5}$

Tables 6 - 8 contain the fixation numbers for high and low contrast pages.

Table 6: Number of fixations for a high contrast page

Scr.	UD-enabled website				
	Mean	Std. Dev.	Variance	Conf. Int.	Shapiro-Wilk
1	5.4	5.44	29.60	3.89	0.80
2	10.9	10.64	113.21	7.61	0.84
3	4.5	1.64	2.72	1.18	0.91
4	5.8	2.25	5.06	1.61	0.89
5	8.2	6.62	43.95	4.74	0.79
6	5.6	2.87	8.26	2.05	0.95
7	6.5	2.46	6.05	1.76	0.92
8	9.8	4.70	22.17	3.36	0.76
9	11	5.92	35.11	4.23	0.92
10	5.7	1.88	3.56	1.35	0.96

Table 7: Number of fixations for the low contrast page

Scr.	No-UD website				
	Mean	Std. Dev.	Variance	Conf. Int.	Shapiro-Wilk
1	15.9	16.86	284.54	12.06	0.78
2	17.9	11.15	124.32	7.97	0.89
3	15	11.24	126.44	8.04	0.85
4	14.5	8.94	80.05	6.40	0.85
5	9	4.13	17.11	2.95	0.94
6	11.9	5.51	30.32	3.93	0.98
7	11.5	5.64	31.83	4.03	0.92
8	18.1	12.62	159.43	9.03	0.71
9	23.2	13.91	193.51	9.95	0.91
10	17.6	10.96	120.26	7.84	0.88

Table 8: Levene's test and t-test for pages with different contrasts

	Test Levene’s	T-test
Screen 1	2.37	$7.73 * 10^{-2}$
Screen 2	0.08	$1.68 * 10^{-1}$
Screen 3	7.95	$9.11 * 10^{-3}$
Screen 4	3.11	$7.99 * 10^{-3}$
Screen 5	0.42	$7.50 * 10^{-1}$
Screen 6	2.07	$4.89 * 10^{-3}$
Screen 7	4.61	$1.93 * 10^{-2}$
Screen 8	1.83	$6.72 * 10^{-2}$
Screen 9	4.57	$2.00 * 10^{-2}$
Screen 10	4.64	$3.32 * 10^{-2}$

4.3. Eye tracking study – fixation duration

Tables 9 – 11 contain the fixation times for searching page elements placed in accordance with the generally accepted principles of universal design and elements that do not meet these rules.

Table 9: Mean, standard deviation, variance and confidence interval for the study of the search time for page elements located in places compliant with the generally accepted principles of universal design

Scr.	UD-enabled website Time (ms)			
	Mean	Std. Dev.	Variance	Conf. Int.
1	1678.42	1564.61	2447995.29	732.25
2	1907.94	1812.01	3883383.94	848.04
3	1300.58	701.95	492736.05	328.52
4	1684.47	819.26	671198.46	383.42
5	2196.91	1284.58	1650162.87	601.21
6	1562.29	819.28	671221.19	383.43
7	1817.72	1419.83	2015914.12	664.50
8	2177.73	1526.89	2331414.39	714.61
9	1389.60	629.13	395806.92	294.44
10	1419.14	534.54	285736.24	250.17

Table 10: Mean, standard deviation, variance and confidence interval for the study of the search time for page elements located in places inconsistent with the generally accepted principles of universal design

Scr.	No-UD website Time (ms)			
	Mean	Std. Dev.	Variance	Conf. Int.
1	4831.41	3013.48	9081101.16	1410.35
2	13035.15	7692.57	59175683.37	3600.23
3	5547.35	3793.79	14392883.21	1775.55
4	6297.19	3552.58	12620859.60	1662.66
5	10219.49	5801.92	33662385.35	2715.38
6	5941.09	3477.95	12096150.57	1627.73
7	5273.11	3574.93	12780130.81	1673.11
8	5194.85	3470.65	12045432.56	1624.31
9	4633.13	3335.15	11123246.81	1560.89
10	5078.13	3158.88	9978538.93	1478.40

Table 11: Levene's test and t-test for pages with different arrangement of elements

	Test Levene’s	T-test
Screen 1	4.51	$1.79 * 10^{-4}$
Screen 2	1.68	$2.23 * 10^{-7}$
Screen 3	0.31	$1.69 * 10^{-5}$
Screen 4	5.14	$1.68 * 10^{-6}$
Screen 5	0.31	$5.06 * 10^{-7}$
Screen 6	1.99	$2.94 * 10^{-6}$
Screen 7	1.26	$2.68 * 10^{-4}$
Screen 8	0.41	$1.02 * 10^{-3}$
Screen 9	0.83	$1.24 * 10^{-4}$
Screen 10	1.14	$9.48 * 10^{-6}$

Tables 12-14 show the results of the fixation duration studies for high and low contrast pages.

Table 12: Mean, standard deviation, variance, and Confidence Interval for high contrast page element search time study

Scr.	UD-enabled website Time (ms)			
	Mean	Std. Dev.	Variance	Conf. Int.
1	1804.18	1542.37	2378906.54	1103.34
2	3417.68	2637.59	6956881.90	1886.81
3	1310.69	377.96	142855.73	270.37
4	1454.97	408.92	167220.23	292.52
5	2162.55	1931.44	3730480.22	1381.67
6	1622.28	734.66	539732.52	525.54
7	1694.12	731.79	535527.33	523.49
8	2541.17	884.40	782171.50	632.66
9	3044.46	1824.92	3330349.51	1305.47
10	1431.41	512.44	262599.42	366.58

Table 13: Mean, standard deviation, variance, and Confidence Interval for low contrast page element search time study

Scr.	No-UD website Time (ms)			
	Mean	Std. Dev.	Variance	Conf. Int.
1	4976.25	4029.96	16240641.52	2882.86
2	5892.29	2638.92	6963903.92	1887.77
3	4827.24	3922.59	15386790.30	2806.05
4	4748.96	2811.99	7907340.59	2011.58
5	3866.21	2481.01	6155390.26	1774.80
6	4374.55	1979.56	3918657.82	1416.09

7	3829.01	1933.06	3736746.42	1382.83
8	6842.46	4329.81	18747217.79	3097.35
9	7629.29	4827.16	23301490.09	3453.14
10	6038.32	4671.37	21821701.92	3341.69

Table 14: Levene's test and t-test for pages with different contrasts

	Test Levene’s	T-test
Screen 1	2.16	$3.20 * 10^{-2}$
Screen 2	0.01	$5.03 * 10^{-2}$
Screen 3	7.88	$1.13 * 10^{-2}$
Screen 4	10.55	$1.77 * 10^{-3}$
Screen 5	0.55	$1.04 * 10^{-1}$
Screen 6	8.01	$6.40 * 10^{-4}$
Screen 7	6.59	$4.29 * 10^{-3}$
Screen 8	12.82	$6.49 * 10^{-3}$
Screen 9	4.71	$1.16 * 10^{-2}$
Screen 10	5.18	$6.18 * 10^{-3}$

4.4. LUT survey

The WUP factor obtained using the LUT questionnaire were subjected to statistical analysis, i.e. calculation of the mean, standard deviation, variance and Levene's test. The results are presented in Table 15.

Table 15: WUP coefficients for LUT questionnaires

Participant	UD-enabled service WUP score	Non-UD service WUP score
1	4.88	3.13
2	4.89	3.46
3	4.69	2.22
4	4.80	3.19
5	4.73	2.49
6	4.98	3.56
7	4.78	2.39
8	4.67	3.43
9	4.69	3.25
10	4.83	3.42
Mean	4.79	3.05
Std. Dev.	0.01	0.24
Variance	0.11	0.49
Test Levene	6.39	

4.5. WAVE Tool

The results of the analysis conducted by the WAVE tool are presented in Table 16. The results were obtained with the use of a web browser plug-in and placed in the table for comparison.

Table 16: WAVE analysis results

Wave category	Sub-category	No. of errors site without UD	No. of errors site with UD
Errors	Missing alternative text	80	0
	Linked image missing alternative text	10	0
	Missing form label	2	5
	Empty button	22	1
	Empty link	2	3
	TOTAL	116	9
Contrast Errors	Very low contrast	335	3
	TOTAL	335	3
Alerts	Select missing label	0	1
	Redundant alternative text	50	2
	A nearby image has the same alternative text	5	0
	Skipped heading level	3	0
	Possible heading	3	0
	Redundant link	129	0
	Noscript element	2	1
	Very small text	38	1
	Redundant title text	6	0
	Accesskey	0	1
	Tabindex	0	1
	TOTAL	236	7
Features	Alternative text	8	0
	Null or empty alternative text	36	10
	Linked image with alternative text	110	2
	Form label	2	0
	Language	1	1
	Skip link	0	2
	Skip link target	0	1
	TOTAL	157	16
Structural Elements	Heading 1	1	2
	Heading 2	13	13
	Heading 3	17	0
	Heading 5	1	0
	Heading 6	4	0
	Unordered list	585	5
	Inline frame	4	0
	Header	1	1
	Navigation	8	1
	Main content	1	1
	Footer	1	1
	TOTAL	636	24
ARIA	ARIA	4	10

	ARIA label	4	18
	ARIA tabindex	6	9
	ARIA alert or live region	1	0
	ARIA hidden	31	6
	TOTAL	46	43

5. Discussion and conclusions

The purpose of this article was to perform a comparative analysis of graphical interfaces of two websites. Literature review and a comparative analysis on the basis of the obtained research results allowed for an unambiguous conclusion of the hypotheses: “Higher interface contrast affects the visibility and speed of searching for individual elements of user interface” and “The arrangement of interface elements has a significant impact on navigating the website”.

Using the WAVE Evaluation Tool, errors of both services were determined in three categories: contrast errors, page element structure and ARIA. Compared to the implemented application meeting the principles of universal design, the Empik website had many more errors from the above-mentioned categories what can conduct to lower comfort of using the website.

Based on the conducted eye tracking study, both hypotheses "Higher interface contrast affects the visibility and speed of searching for individual elements" and "The arrangement of interface elements has a significant impact on the effectiveness of navigating the website" have been confirmed. The purpose of the first set of scenarios was to test the time needed to locate certain elements on the interfaces of low and high contrast pages. By analyzing the results from tables 12-14, it can be concluded that the study participants needed an average of 2 times less time to find all the components on the high contrast page, while maintaining the average number of fixations twice as low. The search times for both the low and high contrast website were similar, but this was due to the fact that the elements were located in places compliant with the generally accepted principles of web application design, so that the user, after reading the command, intuitively directed his eyes, regardless of the contrast, in a given area of the interface. The second set of scenarios was responsible for determining the time needed to find elements placed in places compatible and inconsistent with the generally accepted principles of universal design for this type of pages. Based on the results from tables 9-11, it can be seen that the study participants took an average of almost 4 times more time to locate all components located in places that do not comply with generally accepted design standards. In this case, the average number of fixations was three times higher. Similarly, to the first set of scenarios, some users searched for both sets of items at a similar time, which could be caused by their proficiency in navigating pages or by accidentally finding the item they are looking for.

Based on the analysis of the number of fixations for the study of the search time of page elements located in places compliant and incompliant with the generally accepted principles of universal design from tables 3 and 4, it can be clearly stated that the samples have a normal distribution. Moreover, the data in table 5 indicate that the samples have a homogeneous variance and are statistically significantly different. Similar conclusions were drawn when analyzing the number of fixations for pages with high and low contrast (table 6 – 7). The tested samples have a normal distribution, homogeneous variance and in 9 out of 10 cases they are statistically significantly different.

When analyzing the fixation duration data for different arrangement of elements (table 11), it can be stated that all samples have homogeneous variance and are statistically significantly different. Similar conclusions were drawn when analyzing the fixation duration for pages with different contrast (table 14). The tested samples in 9 out of 10 cases have a homogeneous variance and are statistically significantly different.

The study conducted by filling in a subjective questionnaire confirmed that the website designed in accordance with the principles of universal design is more user-friendly. The study participants rated the page that fulfilled the principles of universal design 57% higher than the page that did not meet the principles of universal design (table 15). The biggest difference in the survey results was observed for the area related to the choice of colors and the structure of the website. The questions in this section were rated higher by 1.875 on average. The smallest differences were in the area of text, nomenclature and labels and amounted to 1.64 on average.

When analyzing the available literature, it was noticed that many professionally designed websites have significant accessibility errors. They do not have the ability to change the contrast, change the size of the elements and do not introduce new technologies. In addition, WAVE has been found to be the best tool for developers to examine web pages for WCAG 2.0 availability. Other tools do not have the ability to accurately diagnose page problems in all three main categories: contrast errors, page element structure, and ARIA.

The conducted analysis confirmed that taking into account the principles of universal design when creating websites improves their usability, transparency, intuitiveness and accessibility. The application becomes available to a wider audience.

Literature

[1] C. Duarte, I. Matos, J. Vicente, A. Salvado, C. M. Duarte, L. Carriço, Development Technologies Impact in Web Accessibility, the 13th Web for All Conference (2016) 1–4, https://doi.org/10.1145/2899475.2899498.

[2] M. Eyadat, D. Fisher, Web accessibility in information systems, International Journal of Web Information Systems 3(4) (2007) 363–377, https://doi.org/10.1108/17440080710848134.

[3] M. Ferati, B. Vogel, Accessibility in Web Development Courses: A Case Study, Informatics 7(1) (2020) 8, https://doi.org/10.3390/informatics7010008.

[4] M. Providenti, R. Zai, Web accessibility at Kentucky's academic libraries, Library Hi Tech 25(4) (2007) 494–508, https://doi.org/10.1108/07378830710840455.

[5] P. Panchekha, A. T. Geller, M. D. Ernst, T. Zachary, K. Shoaib, Verifying That Web Pages Have Accessible Layout, 39th ACM SIGPLAN Conference on Programming Language Design and Implementation (2018) 1–14, https://doi.org/10.1145/3192366.3192407.

[6] E. M. Pivetta, C. Flor, D. S. Saito, V. R. Ulbricht, Analysis of an Automatic Accessibility Evaluator to Validate a Virtual and Authenticated Environment, International Journal of Advanced Computer Science and Applications 4(4) (2013) 15–22, https://doi.org/10.14569/IJACSA.2013.040403.

[7] I. V. Ramakrishnan, V. Ashok, S. M. Billah, Non-visual Web Browsing: Beyond Web Accessibility, Universal Access in Human–Computer Interaction 10278 (2017) 322–334, https://doi.org/10.1007/978-3-319-58703-5_24.

[8] N. Kesswani, S. Kumar, Accessibility analysis of websites of educational institutions, Perspectives in Science 8 (2016) 210–212, https://doi.org/10.1016/j.pisc.2016.04.031.

[9] Serwis internetowy sklepu empik, https://www.empik.com/, [01.02.2022].

[10] Sklep internetowy spełniający zasady projektowania uniwersalnego, http://magister.cba.pl/, [01.02.2022].

[11] Kompendium wiedzy o testach oraz źródło nowin ze świata testowania, https://testerzy.pl/baza-wiedzy/artykuly/projektowanie-uniwersalne, [26.01.2022].

[12] Walidator WAVE, https://wave.webaim.org/, 1.02.2022].

[13] Gazepoint GP3 HD Eye Tracker, https://www.gazept.com/product/gp3hd/, [01.06.2022].

[14] M. Miłosz, Ergonomia systemów informatycznych. Biblioteka Cyfrowa Politechniki Lubelskiej, Lublin 2014.