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Analysis of how universal design principles impact on the perception of virtual museum interfaces

Analiza wpływu zastosowania projektowania uniwersalnego na postrzeganie interfejsów wirtualnych muzeów

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Abstract
The research presented in this paper aims to analyse the impact of using universal design in implementation of virtual museum interfaces to user perception. The experiment uses collaboration with the Museum of the History of the City of Lublin to create the web application which presents virtual exhibits. The application was based on the React JavaScript framework, which enabled the creation of a basic web interface and the React 360 to generate the three-dimensional view. During research, the implemented application was compared with the muzeumpuck.wkraj.pl website, which does not conform to the universal design principles. The main research method consisted of eye-tracking technology and the LUT survey. The analysis of the results shows the interface which follows the principles of universal design was easier to navigate. The time of searching for specific elements on that interface was shorter than in other applications as well.
Keywords: universal design; virtual museum; eye tracking; LUT survey

Streszczenie
Badania przedstawione w niniejszym artykule mają na celu analizę wpływu zastosowania projektowania uniwersalnego w implementacji wirtualnych interfejsów muzealnych na percepcję użytkowników. W celu stworzenia aplikacji internetowej, która prezentuje wirtualne eksponaty, nawiązano współpracę z Muzeum Historii Miasta Lublina. Aplikacja została oparta na javascriptowym szkielecie programistycznym React, który umożliwił stworzenie podstawowego interfejsu webowego oraz React 360 do wygenerowania trójwymiarowego widoku. W trakcie badań porównano zaimplementowaną aplikację z serwisem muzeumpuck.wkraj.pl, który nie spełnia zasad projektowania uniwersalnego. Główną metodą badawczą była technologia eye-trackingowa oraz lista kontrolna LUT. Z analizy wyników wynika, że interfejs zgodny z zasadami projektowania uniwersalnego był łatwiejszy w nawigacji. Czas wyszukiwania poszczególnych elementów na tym interfejsie był również krótszy niż w innej aplikacji.
Słowa kluczowe: projektowanie uniwersalne; wirtualne muzeum; eye tracking; ankieta LUT

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1. Introduction

At present, the majority of cultural facilities are working on expanding their virtual offer by adding interactive elements to the website interfaces. One of such elements is a virtual walk which allows you to get interactive with the exhibitions and attractions of the museum. Users willingly take advantage of the possibility of three-dimensional navigation around the premises of the facility and finding interesting facts about the exhibits [1].

Each interface differs in visual and implementation features. Currently, there is a large pool of technologies that enable the creation of virtual views. Depending on the needs, such solutions can offer a number of additional functionalities and facilitations, such as changing the contrast, using of an virtual guide or zooming in information about the exhibits after hovering over them.

2. The purpose of the work and hypotheses

This study aims to analyse the impact of applying the principles of Universal Design (UD) in the implementation of a virtual museum interface on the user's perception. The research is based on checking the user's reaction time and the ease of navigating the application interface. Based on the literature review, the following hypotheses were put forward:

H1: The interface designed in accordance with the UD pattern, improves the user's perception of the quality of the virtual museum interface.

H2: The perception of interface elements differs depending on gender.

3. Literature review

Universal Design is implemented in many areas of life, including in the GUI design. Many studies can be found on the topics covered in this study.

Articles [1-3] explored how to create a virtual museum application using different technologies. The authors are searching for the best solutions that will allow for a uniform architecture of the application, and at the same time the largest and most realistic possibilities of interaction with the website and virtual exhibits.

The aim of the research presented in [4-7] was to examine the perception of exhibits by visitors. The

authors tried to identify a general pattern of interpretation of the images. As a result of the experiments, it was shown that despite the inevitable variability between subjects, there were common basic patterns of fixation of gaze, but due to the wide variety of results, the researchers failed to emerge a general pattern in which works of art are perceived.

In the study [8], the author discuss the importance of using UD in the process of implementing solutions. She pays attention to the impact of UD principles on the accessibility and usability of applications.

Articles [9-10] discuss user expectations for virtual museum interfaces. The authors focus on adapting the interface in such a way that it can reflect the user experience in the real world as faithfully as possible.

Based on the literature review conducted, no studies were found on the impact of the use of UD in virtual museum interfaces on users' perceptions and whether perceptions of interfaces in virtual museums differ by gender.

4. The interface project and implementation

The experiment described in this paper required the creation of a virtual museum interface, which was created in cooperation with the local museum - the Museum of the History of the City of Lublin. The interface was implemented using the React framework [11], which allowed the creation of a main website on which a three-dimensional application was embedded.

The second element of the interface is a three-dimensional application, which was created using the React 360 framework [12]. The website uses panoramic photos to create a 360° view which is the main background of the application. The structure of the view is created on the basis of assigning coordinates for the places of occurrence of given elements, such as, for example, arrows moving around the view or additional close-ups of elements imitating the zoom. The Figure 1 shows a snippet of code that creates the home page of a three-dimensional view.

```
<html>
  <head>
    <title>Muzeum Historii Miasta Lublina</title>
    <style>body { margin-top: 20; }</style>
    <link rel="stylesheet" href="style.css">
    <meta name="viewport" content="width=device-width, initial-scale=1, user-scalable=no">
  </head>
  <body>
    <div id="container">
      <header class="site-header">
        <div class="container">
            <div class="site-header-inner">
                <nav id="topnav">
                    <a id="logo" class="nav-link" href="home.html">Muzeum Historii Miasta Lublina</a>

                    <a class="nav-link" href="opis.html">Opis Muzeum</a>
                    <a class="nav-link" href="historia.html">Historia Muzeum</a>
                    <a class="nav-link" href="wizyta.html">Wizyta</a>
                    <a class="nav-link" href="index.html">Wirtualna wycieczka</a>
                    <a class="nav-link" href="kontakt.html">Kontakt</a>
                    <a class="nav-link" href="#"></a>
                </nav>
            </div>
        </div>
    </header>
    </div>
    <script src="./client.bundle?platform=vr"></script>
    <script>
      React360.init(
        'index.bundle?platform=vr&dev=true',
        document.getElementById('container'),
        {
          assetRoot: 'static_assets/',
        }
      );
    </script>
  </body>
</html>
```

Figure 1: Implementation code of main page of a three-dimensional view.

The final appearance of the 3D application is shown in Figure 2.

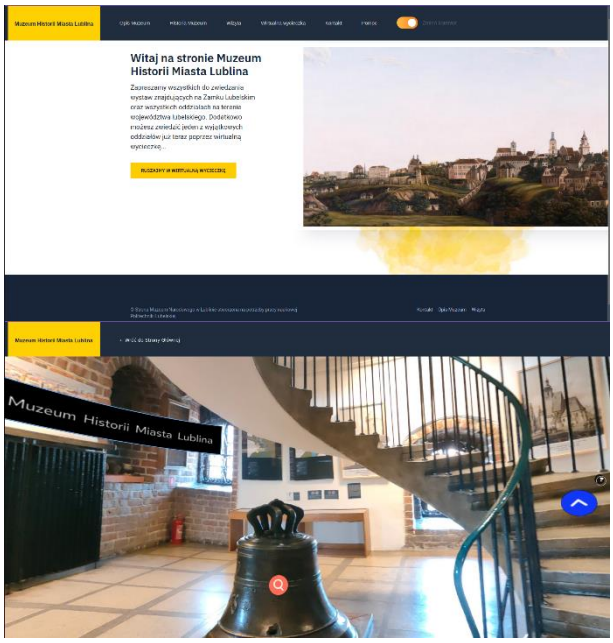


Figure 2: The final view of a three-dimensional application.

5. Research methods

The experiment was conducted based on two methodologies:
- examination using an eye-tracking device;
- examination using the Lublin University of Technology (LUT) survey [13].

Each of the methods required the use of a separate research scenario.

5.1. Research groups

Twelve participants, including 5 men and 7 women with experience in using websites took part in the study. They, regardless of gender, were asked to complete the given tasks according to the scenarios in the eye-tracker study and to evaluate the applications using the LUT survey.

5.2. Eye-tracking study

The first stage of the experiment involved the eye-tracker equipment [14]. The test stand consisted of a monitor and a stationary eye-tracking device attached to it with the specifications specified in Table 1.

Table 1: Eye-tracker specifications

Accuracy of the viewing angle	0.5 - 1.0 degrees
Sampling rate	60 Hz or 150 Hz
Calibration	5- or 9-point
Permissible head movement	35 cm (horizontal) x 22 cm (vertical)
Depth of head movement	±15 cm
Physical parameters (dimensions)	235 x 45 x 47 mm

The participants were divided by gender. Users were asked to perform specific actions on the user interface of the virtual museum website in accordance with re-

search scenarios. For this purpose, each of the existing websites [15] and created for the purpose of the study, was tested in two variants.

The following were tested:

- time to perform tasks from the research scenario;
- interface elements on which the eyes of the subjects were focused.

A single scenario included tasks such as entering search data and finding an element on a page. An exemplary usability test scenario is presented in Table 2.

Table 2: Sample research scenario

Name: Analysis of the speed of locating interface elements.		
Aim of the research: Verification of the impact of the arrangement of elements in the user interface on the speed of locating.		
Initial conditions: Presenting the user with successive views.		
Postconditions: The data collected from the eye-tracker was saved after the completion of the scenario.		
Study participants: 12		
List of tasks:		
No.	**Description**	**Result**
1	Launching the interface	The user launches the interface
2	Locate the virtual walk view button	The user finds the button and presses it
3	Locating object from the attached photo	The user moves around the view and finds the designated object
4	Locating an icon with arrow	The user moves view and finds icon
5	Exit virtual walk view	The user locates the exit button and leaves the view

5.3. Research using the LUT Survey

The next stage was to conduct a study using the LUT questionnaire [14]. Users assessed the quality of the website interface on the basis of a specially prepared survey. For the purpose of the study, 4 areas consisting of 8 sub-areas were selected. The questions were rated on a scale of 1 to 5, with 1 being the worst and 5 being the best. Each participant was asked to complete a questionnaire after checking the website. Aspects such as the ease of finding elements on the website, ease of navigation between sections and the processes that must be performed on the website in order to obtain the appropriate result in the form of receiving specific information on the website were assessed. The exact content of the LUT questionnaire is presented in Table 3.

Table 3: Scope of researched areas – the LUT survey, developed on the basis of [14]

Area	Sub-area	Question
Navigation and structure	Ease of navigation	Is access to all sections of the application easy and intuitive?
		Is access to all the functions of the application easy and intuitive?
	Information structure	Is the structure of the information well thought out?
		Is the information structure consistent?
		Is the structure of the information understandable to the user?
Messages, feedback, user support	Feedback and help	Is the help content available to the average user?
		Is the help content understandable to the average user?
		Are the presented hints or solutions to problems possible to perform by an ordinary user?
Application interface	Layout	Is the layout legible?
		Is the layout adapted to different resolutions?
		Is the layout adapted to mobile devices?
		Is the layout consistent?
		Does the layout support the implementation of tasks?
	Choice of colours	Is the contrast between the text and the background adequate?
		Does the choice of colours allow the use of the application by people with colour vision disorders?
		Does the choice of colours allow you to use the application with the use of various types of displays?
Content of subpages	Texts	Are they understandable to the user?
	Nomenclature	Is the naming used in the app consistent?
		Is the naming used in the app understandable?
	Labels	Do the labels used in the interface provide enough information?
		Do the interface elements have the necessary labels?

Participants focused on LUT areas such as "Navigation and Structure", "Messages, Feedback, User Support", "Application Interface", "Page Content" with each question scaled from 1 to 5, with 1 being the worst score and 5 the best. Working with both services, users were expected to perform the same set of tasks.

After completing all tasks, the users received questionnaires to evaluate their experience. An example scenario of testing the service before completing the survey:

1. Determining where the user is currently located.
2. Locating individual sections of the interface: (History of the object, Help, Contact, Virtual museum).
3. Testing the buttons and links in each section.

In order to analyze the obtained results, the expert method with the use of lists and the processing of the experimental results were used.

6. Results

6.1. The eye-tracker study result

During this study, the participants performed the same scenario for the created interface and the existing interface [15]. Interaction times of the subjects and their focus on specific elements were measured. The time statistics are presented in Table 4 and Table 5, taking into account the maximum total time, the minimum total time, the average time, the standard deviation and the median for three groups: all participants, women and men.

Table 4: Test time results of the created interface compatible with UD

	Maximum total time(s)	Minimum total time (s)	Average time (s)	Standard deviation (s)	Median (s)
All	17.44	7.14	11.76	3.21	10.32
Women	16.98	8.68	11.82	3.36	9.64
Men	17.44	7.14	11.73	3.14	10.64

Table 5: Test time results of the interface incompatible with UD

	Maximum total time(s)	Minimum total time (s)	Average time (s)	Standard deviation (s)	Median (s)
All	43.61	19.44	30.41	6.95	28.77
Women	43.61	19.44	30.03	7.54	27.98
Men	41.51	24.2	30.93	5.99	29.57

Additionally, the result data is presented in boxplots in Figure 3 and Figure 4.

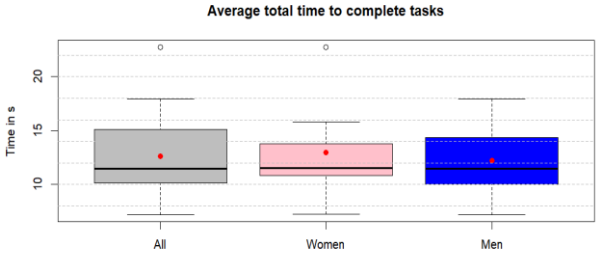


Figure 3: Average total time to complete tasks for the created interface, complying with UD.

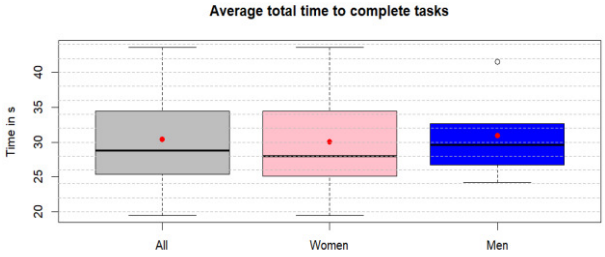
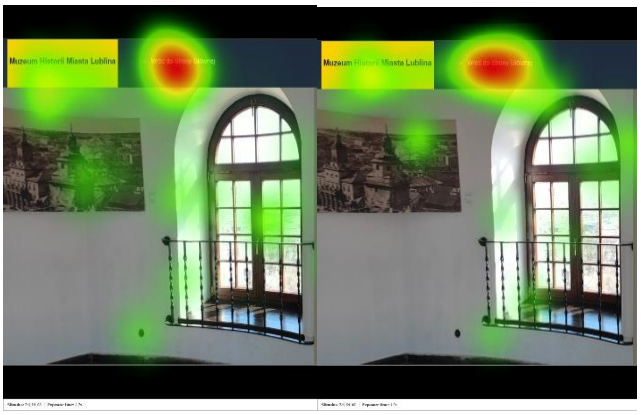


Figure 4: Average total time to complete tasks for the interface not complying with UD.

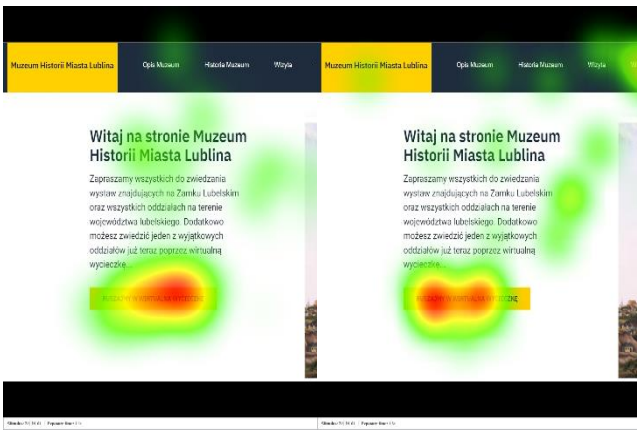
Boxplots (Fig. 3 and Fig. 4) show the dispersion of statistical data of the tested time samples, the red dot marks the average times for a given group, while the horizontal thick line shows the median time. The following conclusions were drawn on the basis of the presented time results.

The average times for each of the three groups are very similar across the same interface. The interface created in accordance with the principles of UD allows for a faster user response than non-UD interface. The average time to complete a task is 18.65s longer for the interface that does not follow the principles of UD which is more than 2 times slower than in the case of the interface that complies with these principles. Additionally, it can be seen that men's minimum task completion time is more than 3 times greater for a non-UD application. All time statistics are much lower for the application created in accordance with UD principles.



a) eye focus for men on the interface

b) eye focus for women on the interface



c) male eye focus on the virtual museum homepage

d) female eye focus on the virtual museum homepage

Figure 5: Heatmaps a), b), c), d) depending on gender of subjects.

Another aspect examined using the eye-tracker was the perception of the interface by women and men. H2 assumed that the perception would differ depending on the gender of the subjects. In order to test the hypothesis based on the study of navigating the interface that meets the principles of UD heatmaps were created that reflect the focus of the eyes on individual views of the subjects. The results are presented in Figure 5.

Based on the analysed heatmaps, it can be seen that the focus of sight differs depending on the gender of the subjects. The most frequently focused areas are marked in red, as the frequency of eye focus decreases, the colour gradually changes to green. In most of the heatmaps studied, female gaze was more diffused than male gaze.

Although there are slight differences in eye focus, they are not clear enough to be able to define on their basis whether the examined person is a man or a woman.

6.2. The LUT survey result

During the LUT survey, the participants assessed the interface features by answering questions to the given subareas on a scale of 1 to 5. Based on their assessments, the WUP index [14] was calculated, which is the average of the subareas and areas specified in Table 6.

Table 6: Calculations of the WUP indicator based on the LUT survey

Area	Subarea	Avg for interface not complying with UD		Avg for created interface, complying with UD	
Navigation and structure	Easy to navigate	3.25	3.07	5	4.903
	Information structure	2.889		4.806	
Messages, feedback, user help	Feedback and help	2.604	2.604	4.806	4.806
Application interface	Layout	2.883	2.859	4.9	4.839
	Choice of colours	2.833		4.778	
Content of subpages	Texts	2.917	3.07	4.917	4.875
	Nomenclature	3.25		4.958	
	Labels	3.042		4.75	
Total average		2.901		4.856	

Based on the obtained results (Table 6), it can be concluded that the interface that is not based on the principles of UD received definitely worse ratings from users. It caused some difficulties in using and finding the functionality. The weakest subarea is feedback and help, which turned out to be insufficient according to the users' requirements. On the other hand, the interface supporting the principles of UD received very high and fairly uniform results, which suggests that each of the sub-areas satisfies the requirements of users to a sufficient extent.

7. Discussion and summary

The purpose of this paper was to conduct a comparative analysis of two websites that present virtual exhibits. On the basis of the research methods taken into account, the authors had the opportunity to verify two formulated hypotheses. The first of them concerned the impact of UD on improving the perception of the virtual museum interface by the user, and the second was related to the influence of gender on the way of using the interface. Two methods were used in the study.

The results of the eye-tracking test showed that an interface designed in accordance with the principles of UD allowed users to complete the tasks indicated in the scenario faster, compared to an interface that did not comply with these principles. The time difference was about 61.5%. This result underscores the great importance of UD in increasing website accessibility and a positive user experience.

The LUT survey provided information on the perception of the interface of the virtual museum website by individual users. Areas such as navigation and structure, messages and feedback, application interface and page content were assessed. Participants rated these areas on a scale of 1 to 5. Also in this aspect a large impact of the presence of UD on the results obtained can be seen. The non-UD website scored significantly lower than UD website. The difference was about 67% in favour of the latter. On this basis, we can conclude that the time studies confirm the assumptions of hypothesis H1.

To verify the second gender hypothesis, an eye-tracker study was also used. In the presented graphs (Figure 3 and Figure 4) and heatmaps (Figure 5) it can be seen that the differences in the time of performing tasks and the way of perceiving the interface differ slightly depending on gender. The authors of this paper were unable to distinguish significant differences between the behaviour of users of both sexes and the time of execution of the scenarios assigned to them. It can therefore be concluded that gender does not matter in the perception of website interfaces. That means that H2 cannot be confirmed by the results of the above studies.

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