

Analysis of Compliance with WCAG Guidelines Regarding Contrast Implementation in an E-Learning Quiz

Analiza prawidłowości implementacji wytycznych WCAG w zakresie kontrastu dla kursu e-learningowego

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Abstract

In the process of distance learning, modern information and educational solutions are increasingly employed. The introduction of tools facilitating compliance with WCAG guidelines to course creators, enhances content accessibility for individuals with disabilities, eliminating barriers to education access. This aligns with the concept of universal design, aiming to create courses and instructional materials accessible to a broad audience, regardless of individual needs, abilities or conditions. While this is a standard in web design, it is often overlooked in distance learning and course design. This paper focuses on analyzing the correctness of implementing a component allowing the assessment of WCAG compliance in designed quizzes using an exercise creator. The implementation was based on the Quizer e-learning platform. Quizzes in the field of cybersecurity were designed to meet contrast guidelines according to the WCAG 2.1 standard, followed by user testing. The research results confirmed the correctness of the applied solutions and emphasized the necessity of designing IT tools considering potential disabilities of future users of e-learning quizzes.

Keywords: e-learning platform; quiz; WCAG; contrast

Streszczenie

W procesie kształcenia na odległość coraz częściej stosowane są nowoczesne rozwiązania informatyczne i dydaktyczne. Wprowadzenie do kreatorów kursów narzędzi umożliwiających spełnienie wytycznych WCAG zwiększa dostępność treści dla osób z niepełnosprawnościami znosząc bariery w dostępie do edukacji. Wpisuje się to w ideę projektowania uniwersalnego. Polega to na tworzeniu kursów i materiałów dydaktycznych tak, aby były one dostępne dla jak najszerszej grupy odbiorców, niezależnie od ich indywidualnych potrzeb, zdolności czy warunków. Jest to obecnie standard w projektowaniu stron i serwisów internetowych, natomiast w kształceniu na odległość i projektowaniu kursów dość często ten aspekt jest pomijany. Niniejsza praca dotyczy analizy prawidłowości implementacji komponentu umożliwiającego badanie spełnienia wytycznych WCAG w projektowanych quizach przy wykorzystaniu kreatora ćwiczeń. Bazą do implementacji komponentu była platforma e-learningowa Quizer. Zaprojektowano quizy z zakresu cyberbezpieczeństwa spełniające wytyczne dotyczące kontrastu według standardu WCAG 2.1 a następnie przeprowadzono badania na użytkownikach końcowych. Wyniki badań potwierdziły prawidłowość zastosowanych rozwiązań i potrzebę projektowania narzędzi informatycznych uwzględniających ewentualne niepełnosprawności przyszłych użytkowników quizów e-learningowych.

Słowa kluczowe: platforma e-learningowa; quiz; WCAG; kontrast

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1. Introduction

In today's world, information and communication technologies significantly influence various aspects of life [1], including education [2]. E-learning, which is teaching based on internet technologies, is gaining popularity due to its accessibility, flexibility and the ability to personalize the learning process [3]. Its application has been intensified by the COVID-19 pandemic [4]. The pandemic has demonstrated that in some cases, e-learning can become the primary form of education. E-learning allows flexible knowledge acquisition, independent of location and time, through interactive platforms, video conferences and multimedia materials [5]. However, a significant issue is the limited access to e-learning for

individuals with various disabilities. The World Health Organization estimates that over a billion people worldwide live with some form of disability, affecting their access to education [6]. Individuals with disabilities may experience a range of limitations, including difficulties in physical access to buildings, visual or hearing impairments, cognitive disorders, or challenges in interacting with computers.

To ensure equal access to education, it is necessary to develop educational tools and e-learning platforms that take into account the needs of individuals with disabilities [7]. A crucial standard in this regard is the Web Content Accessibility Guidelines (WCAG) 2.1. WCAG 2.1, an international standard, serves as a guide for creating

digital content that is accessible to individuals with various types of disabilities. This standard addresses a range of disability-related challenges, such as limitations in vision, hearing, speech, learning, thinking, movement, language communication and neurological issues [8]. These disabilities may occur individually or in combination, requiring the application of appropriate techniques and solutions to enable access to online content. WCAG 2.1 establishes specific success criteria for each guideline, allowing content creators to verify their compliance with these standards [9].

There are three levels of WCAG 2.1 compliance: A (basic), AA (intermediate), and AAA (highest), each setting progressively more rigorous accessibility requirements. While content meeting the highest level of compliance (AAA) provides a broad range of accessibility, it's important to note that even such content may not be fully accessible to all individuals with disabilities, especially those with more complex cases of impairment. Therefore, the creation of universally accessible digital content requires continuous attention to diverse user needs, as well as adaptation and innovation in design and technology. The design of software and e-learning courses should consider these guidelines to enable individuals with disabilities to access online educational content without limitations [10].

In response to the needs of individuals with disabilities, ongoing efforts and research are being conducted to create and modify educational tools and e-learning platforms to make them more accessible for this user group [11-13]. The e-learning platform 'Quizer' was created with the aim of developing interactive multimedia courses. It enables the preparation of training materials, presentations, as well as comprehensive final test assessments with detailed statistical results. The capability to play courses on various types of mobile devices has reduced the barrier of requiring in-person training, and advanced user monitoring tools provide data on their activity [14].

The aim of the article was:

1. To create a new component that would collaborate with the interactive platform Quizer.pl. This component is intended to enable the creation of interactive exercises that comply with the Web Content Accessibility Guidelines (WCAG) 2.1, focusing on the needs of individuals with visual impairments.
2. To conduct an analysis and evaluation of how effectively the newly created WCAG component has been integrated into the Quizer e-learning platform. This evaluation was based on feedback from users participating in cybersecurity e-learning courses.

2. Research Methodology

The Web Content Accessibility Guidelines (WCAG) are international standards developed by the World Wide Web Consortium (W3C) with the aim of making web content more accessible to individuals with various disabilities [15]. Contrast is one of the key elements of these guidelines, as an appropriate level of contrast between

text and background is crucial for individuals with visual impairments, including those with partial blindness or dyslexia. Contrast helps improve text readability, which is particularly important in e-learning courses where content is primarily delivered in digital form. The analysis of the proper implementation of WCAG guidelines regarding contrast in an e-learning course included the following issues:

1. Evaluation of contrast levels: Verifying whether the designed e-learning courses using the new component meet the specified WCAG standards for contrast between text and background.
2. Case study: Presenting to users the examples of cybersecurity e-learning courses incorporating contrast guidelines and analyzing their survey responses regarding the correctness of the implementation.

In Figure 1, the contrast testing process is presented according to the Web Content Accessibility Guidelines (WCAG). If it was found that the contrast did not meet WCAG requirements, a return to previous steps was necessary for improvement and retesting. The frontend of the Exercise Creator tool on the Quizer platform was developed using Backbone JS. Backbone JS is a programming library that provides a model structure for data. Backbone JS applications feature a structure divided into controllers, views, and models, and are event-driven, responding to changes in data models. Events in Backbone JS are defined using event maps, ensuring an efficient organization and response to user interactions. All new modules and modifications related to WCAG in the Exercise Creator were also implemented using the same technology. JavaScript, a key language in the platform's structure, was used to program most user interface components. The application consists of various elements such as components, containers and triggers. Components are independent software fragments that can be integrated into larger systems. Containers, managed by application servers, control the operation of these components. Triggers, on the other hand, are procedures automatically executed in response to specific events. As a part of adapting the Exercise Creator tool for accessibility and compliance with WCAG 2.1 guidelines, a series of significant modifications were made. The first modification involved creating a new WCAG component. This component was designed to enable keyboard and screen reader support in courses, which is crucial for accessibility. The next step was to add a special WCAG tab to the 'Exercise Creator.' This tab allows course creators to enter alternative texts for non-text elements such as images, icons or animations. As a result, all these elements can be properly interpreted by screen readers, which is extremely important for individuals with visual impairments. Additionally, a feature was implemented that allows screen readers to interpret the HTML code used in exercises and read the added alternative texts. The option to highlight interactive elements of the course was also introduced. This feature is particularly useful for visually impaired users as it enables them to easily identify which element of the

course is currently active. A key change focused on ensuring the ability to select appropriate contrast in designed courses in accordance with WCAG guidelines. A component was implemented to examine and adjust the contrast of individual elements relative to each other, ensuring that the designed courses meet specific visibility guidelines.

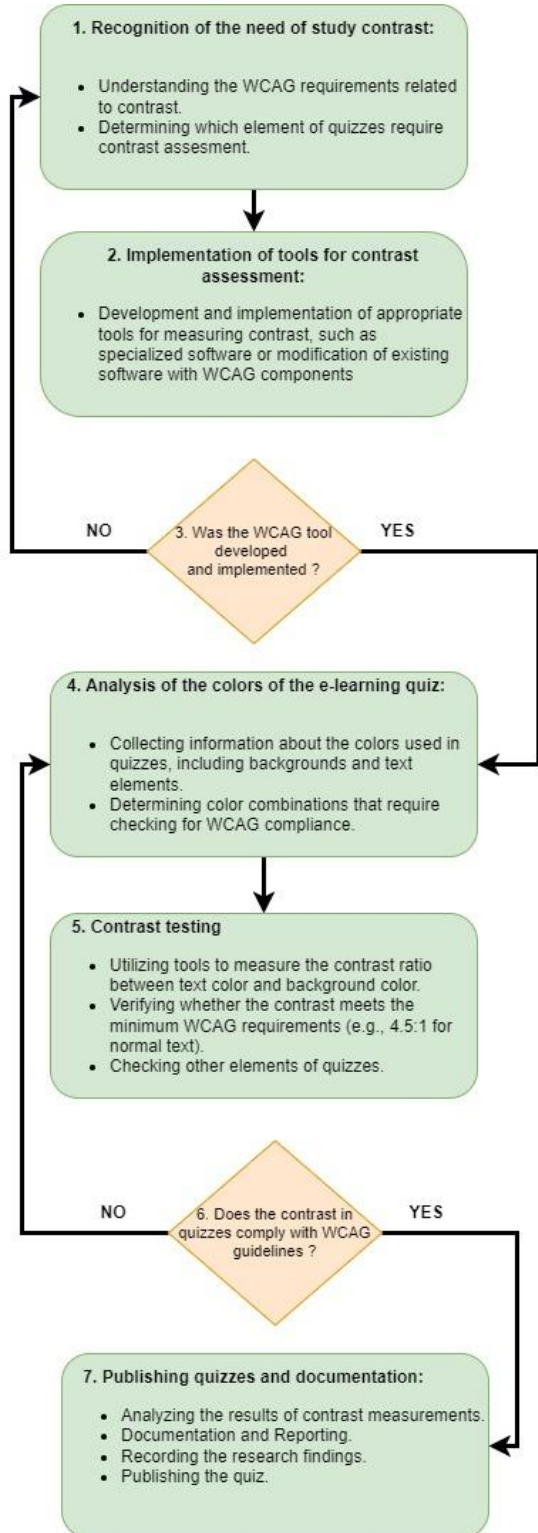


Figure. 1: Diagram of the contrast testing process for e-learning quizzes.

It was embedded in the exercise creator and is available upon user request. The component was created in JavaScript, allowing it to be integrated with the Backbone JS framework. A fragment of the programming solution for the contrast adjustment component is presented in Listing 1 and 2.

Listing 1: Programming solution in JavaScript for the contrast adjustment

```

function changeHexToRGP(hex) {
  var result = /^#?([a-f\d]{2})([a-f\d]{2})([a-f\d]{2})$/i.exec(hex);
  return result ? {
    r: parseInt(result[1], 16),
    g: parseInt(result[2], 16),
    b: parseInt(result[3], 16)
  } : null; }
function gcd (a, b) {
  return (b == 0) ? a : gcd (b, a%b); }
var w = screen.width;
var h = screen.height;
var r = gcd (w, h);
document.querySelector("button").addEventListener("click", function() {
  const ratio = gcd(w,h,r);
});
  
```

Listing 2: The HTML code for script handling

```

<section id="color-contrast" class="open">
<div class="cc-show">
<button class="btn btn-primary">
<span class="arrow">V</span> | Contrast Checker ✓
</button>
</div>
<div id="sample">
<div contenteditable="" id="sample-text"
style="color:rgb(0,0,0);background:rgb(255,255,255)">
Kliknij, by zmienić tekst podglądowy
</div></div>
<div id="boxes">
<div id="aa-large">
<span>Tekst duży</span>
<span>WCAG AA</span>
</div>
<div id="aa-normal">
<span>Tekst normalny</span>
<span>WCAG AA</span>
</div>
<div id="aaa-large">
<span>Tekst duży</span>
<span>WCAG AAA</span>
</div>
<div id="aaa-normal">
<span>Tekst normalny</span>
<span>WCAG AAA</span>
</div>
</div>
<div id="bars">
<div>
<h4>Kolor tekstu</h4>
<div>
<label for="color-1-r" class="red">R</label>
<input id="color-1-r" type="range" min="0" max="255" value="0">
<input id="number-1-r" type="number" min="0" max="255" value="0">
</div><div>
<label for="color-1-g" class="green">G</label>
<input id="color-1-g" type="range" min="0" max="255" value="0">
<input id="number-1-g" type="number" min="0" max="255" value="0">
</div><div>
<label for="color-1-b" class="blue">B</label>
  
```

```

<input id="color-1-b" type="range" min="0" max="255" value="0">
<input id="number-1-b" type="number" min="0" max="255" value="0">
</div>
<input id="color-1-hex" data-target="1" type="text" value="#000000"
maxlength="7">
</div><div>
<h4>Kolor tla</h4>
<div>
<label for="color-2-r" class="red">R</label>
<input id="color-2-r" type="range" min="0" max="255" value="255">
<input id="number-2-r" type="number" min="0" max="255"
value="255">
</div>
<div>
<label for="color-2-g" class="green">G</label>
<input id="color-2-g" type="range" min="0" max="255" value="255">
<input id="number-2-g" type="number" min="0" max="255"
value="255">
</div>
<div>
<label for="color-2-b" class="blue">B</label>
<input id="color-2-b" type="range" min="0" max="255" value="255">
<input id="number-2-b" type="number" min="0" max="255"
value="255">
</div>
<input id="color-2-hex" data-target="2" type="text" value="#FFFFFF"
maxlength="7">
</div> <div>
</section>
    
```

This component analyzes the contrast between text color and background using color codes in RGB and HEX formats. The program compares the color combination and assesses the contrast according to WCAG AA standards for normal and large text, as well as WCAG AAA standards for both types of text. Large text is typically text that is at least 18 points or 14 points if bold. Color matching to comply with WCAG standards is done by adjusting the values of individual color components with sliders. The process continues until the guidelines are met. If the contrast meets the requirements, the user receives a positive signal in the form of green highlighting. In the case where the contrast does not meet standards, the data criterion is highlighted in red, indicating non-compliance. In a situation where yellow text on a black background was compared, the program indicated in green that all four contrast standards are met, as shown in Figure 2.



Figure 2: Sample contrast testing window for a designed quiz with high contrast.

However, when comparing white text on a blue background, the program indicated that most standards are not met (Figure 3), except for one – the WCAG AA standard for larger text, indicating acceptable contrast only in this case. To meet the minimum contrast requirements (AA level), a contrast ratio of 4.5:1 for regular text and 3:1 for headings is necessary. For maximum requirements (AAA level), the ratio is 7:1 for regular text and 4.5:1 for large text [15].



Figure 3: Sample contrast testing window for a designed quiz with low contrast.

Content is considered visually accessible if it achieves at least the minimum contrast level (AA). An exception is made for texts that are part of logos. User interface elements and some graphic elements were also chosen to meet specific contrast requirements. The contrast ratio for these elements should be at least 3:1 in relation to adjacent colors. Importantly, in the design of web content, including e-learning, color cannot be the sole means of conveying information. Users should also have the option to adjust the font size of displayed content, further enhancing its accessibility. The implementation of the WCAG component allowed determining the level of compliance of the designed courses with WCAG guidelines at the stage of their creation.

Two cybersecurity courses on the topic of 'Digital Footprint' were designed to meet WCAG guidelines and were applied in user research. The study was conducted in accordance with ethical standards and included individuals with actual visual impairments. Additionally, participants used headphones to limit the impact of external sounds on their ability to understand the content read by the screen reader. Access to quizzes, including presentations and tests, was conducted online through a web browser. Participants first reviewed the presentation and then proceeded to solve the test. The test ended with providing the result as a percentage of correct answers. It was assumed that the time needed for an adult to complete one quiz should not exceed 5 minutes (300 seconds).

3. Results and Discussion

The sequence of transitions between specific elements was in line with the timeline set in the 'Exercise Creator.' An exemplary view of the quiz window is presented in Figure 4.



Figure 4: Sample drag-and-drop quiz window prepared according to WCAG guidelines.

Elements such as the contrast activation icon and font enlargement were visible on it. While solving the quiz, only the elements on the screen with the 'consider' option

selected in the WCAG tab were visible to users. The planned logic of solving the exercise aligned with the actual method of task execution, and no unexpected actions occurred during the quiz. The use of event actions, such as 'show object with highlight' and 'on object selection,' allowed triggering the desired reactions depending on the planned task-solving path. Users had the option to choose how to solve the exercise (using the mouse or using the keyboard and screen reader). The first user action determined the method of solving the task.

Thanks to the actions, smooth transitions between examples became possible after receiving feedback. The screen reader did not lose its position and set itself on a new object along with the highlight, automatically triggering the screen reader to provide voice information to the user about their location and the expected actions to continue solving specific tasks. Through the collaboration of the screen reader and the ability to plan the exercise-solving path using alternative texts for individual elements, users could freely navigate through the courses using the mouse or keyboard and complete the tasks they started. The conducted tests revealed that for drag-and-drop exercises, specific elements of the exercise are the question, answers, as well as the fields for dragging the answers. When preparing this type of exercise, special attention should be paid to the contrast between the background of the entire exercise and the text layer (instructions, questions, answers) to meet WCAG requirements.

Testing quizzes by individuals with various types of visual impairments or using tools simulating these impairments is crucial to ensure that all elements are accessible and compliant with WCAG guidelines. The prepared survey, filled out by the participants, contained questions exclusively for individuals with actual visual impairments. In the studies involving individuals with actual visual impairments, 14 men and 2 women participated. These individuals had visual impairments ranging from -2 to -6 diopters and astigmatism. The survey included questions presented in Table 1.

Table 1: Research questions included in the survey

No.	The content of the survey question
Q1 (light blue)	Is it visible which element is active during navigation?
Q2 (green)	Did the contrast change positively impact the improvement of content visibility on the screen?
Q3 (blue)	Did the font size change result in an improvement in the perceived text quality?

The results of the survey regarding individuals with actual visual impairments are presented in Figure 5. For question Q1 ("Is it visible which element is active during navigation?"), over 56% of responses were positive, and 25% were neutral. Only 2 individuals responded "rather not," and 1 person responded "definitely not." The impact

of changing the contrast to improve the perception of displayed content was also highly rated, with over 68% of users expressing positive feedback. Two individuals did not provide an opinion. Negative responses were distributed similarly to those in question Q1.

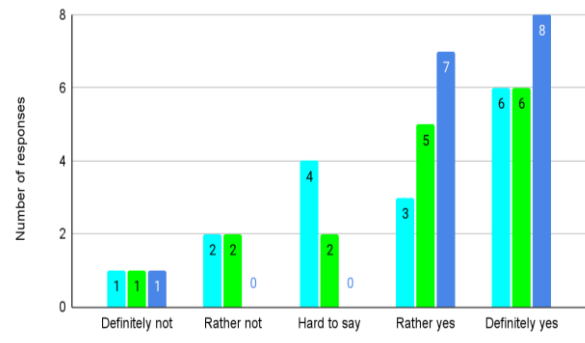


Figure 5: Results of responses to questions Q1, Q2, and Q3.

Changing the font size significantly improved the quality of displayed text (Q3), as confirmed by 94% of individuals with actual visual impairments. The final test results were quite high for the responses, indicating the proper design of the course and the effectiveness of the tools used in both the presentation and quiz test. Over half of the users achieved a perfect score, and all users completed the quizzes within the designated time (below 5 minutes).

4. Conclusions

The article discussed the process of adapting an e-learning exercise creator to the requirements of individuals with visual impairments. Following the implementation of the WCAG component and the analysis of user feedback, several key conclusions were formulated:

1. It is technically feasible to adapt the Quizer e-learning platform to WCAG guidelines, enabling individuals with disabilities, especially visual impairments, to access educational materials. The use of Backbone JS technology facilitated the creation of a component compatible with the Quizer e-learning platform, allowing the development of quizzes in line with WCAG guidelines.
2. By applying suitable color schemes, adjusting the contrast of individual elements, and employing clear highlighting and enlargement of focused elements, educational support for individuals with visual impairments is enhanced.
3. Survey results confirmed that WCAG guidelines were correctly applied in cybersecurity quizzes.
4. Integration of keyboard support and screen reader functionality is crucial for proper navigation and understanding of the quiz, allowing individuals with visual impairments to complete exercises without losing their substantive content.

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