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PSYCHO-PEDAGOGICAL ANALYSIS OF THE ACCESSIBILITY OF DIGITAL LEARNING ENVIRONMENTS FOR VISUALLY IMPAIRED STUDENTS

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Abstract. In the era of global digitalization, it is becoming increasingly essential to create web content that meets the needs of a diverse audience, including people with visual impairments. In Russia, these issues are regulated by the state standard GOST R 52872-2019 and guidelines of the Ministry of Digital Development. Nevertheless, visually impaired users continue to face difficulties in accessing educational, recreational, and social platforms, as compliance with accessibility standards for digital educational environments is voluntary. The accessibility limitations identified necessitated a comprehensive review of online platforms for blind and visually impaired users, as well as the development of targeted solutions to enhance digital educational environments for these users. The following methods were used in the study: Heuristics, data analysis, testing, generalization of the results obtained, statistical data processing (Kolmogorov-Smirnov criterion), methods for evaluating the customer effort index (Customer Effort Score), and elements of a Customer Journey Map (CJM).

The study involved 20 participants (10 blind and 10 visually impaired students aged 15–20 from Moscow, Ulyanovsk, and Cheboksary) who voluntarily completed eight standardized user tasks. The study expands our understanding of how blind and visually impaired users interact with digital learning environments. The findings highlight the need to incorporate both international and local experiences, develop a uniform accessibility standard across countries, evaluate the accessibility of web tools, consider how blind and visually impaired users perceive information and interact with digital spaces, and establish common accessibility standards for developers.

These findings are relevant for developers and researchers working on digital tools for visually impaired users and other accessibility needs.

Keywords: *visual impairment, accessibility, digital learning environment, development*

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Introduction

One of the most critical trends driving progress in various sectors is the rapid introduction of digital tools. Global digitalization also has a decisive influence on the development of education systems. The COVID-19 pandemic has accelerated the introduction of new learning

formats and expanded the range of web tools used in education. Distance learning and digital education formats are now widespread in the modern education market. As these platforms seek to reach a wider audience, they increasingly include students with visual impairments. At first glance, this format appears ideal compared to traditional special or inclusive schools: the teacher works one-on-one with the students, addresses their individual needs, and strives to achieve good academic results. However, such teaching often takes place on self-developed or third-party platforms without considering the accessibility standards for digital learning environments (DLEs) that cater to students with visual impairments.

In this context, the development of DLEs tailored to the needs of visually impaired users is significant. Addressing this challenge can help regulate the work of online educational platforms, improve the quality of their services, and further develop the design and usability of DLEs for both visually impaired people and other vulnerable groups. The experience gained can be applied to other online services frequently used by blind and visually impaired users.

Scientific Novelty

This study employs an integrated approach to addressing the accessibility of DLE for visually impaired users, combining educational, psychological, technological, and legal perspectives. For the first time, empirical data were collected through a multi-parameter assessment of users' experiences with varying degrees of visual impairment when interacting with online school platforms. The main parameters of accessibility – perceptibility, usability, clarity, and reliability – are analyzed from psychological and pedagogical perspectives.

According to international and Russian researchers (Yu. Ivashkina, E. Kosova, O. Miroshnichenko, K. Redkokosh, T. Polilova, A. Solovyeva, M. Charmatz, V. García-Morales, A. Garrido-Moreno, R. Martín-Rojas, Z. Meleo-Erwin, B. Kollia, J. Fera, A. Jahren, C. Basch, C. Mullin, R. Gould, S. Parker Harris, O. Nass, I. Bapiyev, O. Skuliabina, S. Nass, L. Shawn, S. Weissman), an accessible DLE is a DLE that is easily accessible to all learners, regardless of their disability, and meets their specific needs [1–11]. In contrast, a DLE is considered inaccessible if it contains barriers that prevent even a single user from meeting their learning needs.

The design of an accessible DLE is based on the principles of the Access For All and WCAG frameworks, which provide technical guidelines to ensure that platforms and their tools are precise, reliable,

operable, and perceivable [12]. These standards complement each other and should not be applied separately. WCAG defines the mandatory minimum requirements, while Access For All provides optional, user-oriented recommendations for personalization and flexibility.

International practices in designing accessible DLE for visually impaired users are governed by legal frameworks [13]. In the United States, this work is governed by the Americans with Disabilities Act and the Rehabilitation Act (Sections 504 and 508). In the United Kingdom, it is based on the Disability Discrimination Act and the Disability Act (1995, 2005). In Scotland, the accessibility of DLE is guaranteed by the Equality Act. Japan regulates this area through the Basic Act on the Formation of an Advanced Information and Telecommunications Network Society. In China, developers are required to follow the Law on the Protection of Persons with Disabilities. In Switzerland, the relevant legislation is the Federal Act on the Elimination of Inequalities for Persons with Disabilities.

Additionally, the Russian Law on Social Protection of Persons with Disabilities (No. 181, dated November 24, 1995, revised on March 1, 2025), specifically Article 15, which regulates access to social, technical, and transportation infrastructure, does not mention digital accessibility [14]. If digital environments are considered part of the broader social environment, one could assume that these standards also apply to web content.

Since 2019, Russia has been using GOST R 52872-2019 (approved by Rosstandard Order No. 589 of August 29, 2019), which is based on the Web Content Accessibility Guidelines (WCAG) 2.1 [15]. This standard regulates digital accessibility, including for users with visual impairments. However, according to the Law on Standardization in the Russian Federation (June 29, 2015, No. 162), compliance with this standard is voluntary [16]. As a result, its requirements are often followed only superficially.

According to Decree No. 931 of the Ministry of Digital Development, dated December 12, 2022, state websites, municipal platforms, and affiliated organizations are required to provide an alternative version of their websites for users with visual impairments [17]. However, with Decree No. 957 (November 7, 2023), which came into force on September 1, 2024, the obligation for websites to provide tools for the alternative display of web content was lifted [18].

Russian researchers have also studied various aspects of digital environments. A. Kondakov and I. Sergeev consider the digital

environment as a convergent educational space that promotes students' socialization, effective communication, and professional development [19]. According to T. Noskova, achieving these goals requires an interdisciplinary approach to digital environments [20]. The issue of web content accessibility for people with disabilities is comprehensively addressed by A. Guseinova, O. Ilyin, V. Manuilova, N. Polyakova, M. Chetvergova, and others [21–29]. Their solutions can be considered as a starting point for designing digital learning environments for users with visual impairments.

Methodology, Materials, and Methods

This study aims to present a possible approach for designing a digital learning environment (DLE) that is accessible to individuals with visual impairments. The research hypothesis states that the goal can be achieved by fulfilling several vital conditions: Integration of international and national best practices for the accessible design of DLE, development of a unified legal framework, use of analytical data from online school environments, and analysis of how blind and visually impaired people perceive and interact with online content.

Data reflecting the current state of online school platforms is needed to design DLEs that are accessible to visually impaired users. The need to identify general trends in accessible web content shaped both the structure of the 2024 experiment and the selection of diagnostic tools.

Using a random sample, we selected three online schools (the authors did not disclose the names). It is assumed that their students could include people with visual impairments.

Ten blind and ten visually impaired participants, aged 15 to 20, from Moscow, Ulyanovsk, and Cheboksary, took part in the study. Five of the ten blind participants were students in educational institutions for visually impaired children, while the other five attended a vocational school that trains medical masseurs. All blind participants had a residual vision of 0.01% to 0.04%. Of the visually impaired participants, six were students in institutions for visually impaired children, and four were enrolled in a vocational school for medical massage therapy. Their corrected central visual acuity ranged from 0.06% to 20%. According to self-report, all participants had an adequate level of digital literacy.

The DLE test was based on a series of user tasks. This informed the choice of methods, which included a heuristic approach with blind and visually impaired users, content analysis of websites, task-based testing through sequences of related operations, synthesis of results, and statistical analysis using the Kolmogorov–Smirnov test. Additionally,

the study employed the Customer Effort Score (CES) method and elements of the Customer Journey Map (CJM), commonly used in marketing, to assess the user experience.

The user tasks were real-life scenarios in which the participants had to perform a sequence of actions. They were asked to: 1) access the platform; 2) register an account; 3) log in to their account; 4) select one of the areas (e.g., 'Assignments', 'Theory', 'Practical tasks', 'Calendar', 'Lesson plan', 'Additional materials'); 5) complete a task using the platform's tools (e.g. search for lessons, work with additional information sources in text, audio and video formats, etc.); 6) check their answers and compare them with the answers suggested by the system; 7) communicate using the platform's integrated tools; 8) evaluate the accessibility of text, audio and video content and other features.

Tasks 1 to 7 were rated on a 5-point scale: 1 point – the task is not solvable; 2 points – the task can only be solved with the help of a sighted assistant; 3 points – the task is partially solvable; 4 points – the task is solvable but requires a lot of time and effort; 5 points – the task is easily solvable.

Task 8 was evaluated based on the participants' assessment of the platform's accessibility in terms of the perceptibility of materials, user-friendliness of content and tools, clarity of the interface and materials, and the reliability of the platform. A 3-point scale was used: 1 point – the web content does not fulfill the main principles; 2 points – the web content partially fulfills the principles; 3 points – the web content fully fulfills all principles.

To test the accessibility of the DLE, all participants used their PCs with Windows 10 and the screen-reading software JAWS (Job Access With Speech) and NVDA (NonVisual Desktop Access).

Research Results

The analysis of the tasks (1–7) that required a sequence of user actions reflects the typical workflow of an average user. The data indicate that the needs of users with visual impairments are often overlooked in the development of DLE. Specifically:

1. All blind and visually impaired participants (100%) were able to access the platforms without significant difficulties. This task did not take much time.

2. The majority of participants had difficulty registering. Without the help of commonly sighted people, 60% of the blind users (4 pupils and 2 students) and 50% of the visually impaired users (3 pupils and

2 students) were unable to complete the task. They lacked the time given by the web developers to enter an SMS verification code. The participants stated that the limited time caused stress, which negatively impacted their ability to use the keyboard.

40% of the blind users (1 pupil and 3 students) and 20% of the visually impaired users (1 pupil and 1 student) required considerable effort to complete the task. They had to request and re-enter the SMS code several times. The limited time had a negative impact on their performance, and despite repeated attempts, they were unable to complete the registration successfully.

Only 30% of the visually impaired participants (2 pupils and 1 student) completed the task with ease, as their central visual acuity in the better-sighted eye was approximately 20%. They relied mainly on their residual vision to solve the task.

3. All blind and visually impaired participants (100%) were able to access their accounts on the tested platforms successfully. This task did not require much effort from them.

4. When selecting one of the available sections (‘Assignments’, ‘Theory’, ‘Practical tasks’, ‘Calendar’, ‘Lesson plan’, ‘Additional materials’), 100% of the blind participants had difficulties.

Seventy percent of the blind participants (5 pupils and 2 students) had trouble navigating the websites. They first had to guess the purpose of the different sections or tools, relying on some context, and then test these assumptions through trial and error. Many reported that the fear of making mistakes significantly slowed down their actions. In contrast, sighted users with sufficient digital literacy usually perform such tasks automatically by relying on visual cues.

30% of the blind participants (3 students) used the arrow keys to navigate the platform. They stated that they needed a lot of time to understand how the navigation worked. None of the blind users were able to solve the task independently.

When selecting sections on the platforms, 100% of the visually impaired participants initially relied on their eyesight. All participants reported physical discomfort due to the lack of adapted content, which harmed both the speed and quality of their work.

Only 30% of the visually impaired participants used screen reader software to complete the task. Most avoided such aids, probably because they deliberately did not want to identify themselves as visually impaired.

One hundred percent of the visually impaired participants completed the task.

5. Completing the task that required the use of platform tools was a particular challenge for all participants. All blind users required a significant amount of time to locate the desired lesson in the course list and access its content. They found that one of the three platforms had no semantic labeling, which made navigation particularly difficult. When a lesson was selected, a new tab often did not open, forcing users to navigate aimlessly. Further complications arose when tools and text were moved down the page and replaced with new content. This significantly impaired navigation and substantially slowed access to the lesson material.

Users had problems with the lessons because the theoretical content and the exercises were not separated from each other. Navigation through the text and tools was done with the up and down arrow keys. These actions were time-consuming and demanding, as users had to filter out irrelevant information to find the relevant data.

All blind users (100%) had difficulties with almost all information sources on the platforms. Presentations were inaccessible: slides could not be manually advanced, and background music interfered with the screen reader software. As hearing is the primary source of information for blind users, problems with audio settings negatively affect their concentration, efficiency, and understanding of information.

Users also had difficulties with video content: The player on the first platform did not support keyboard control. Illustrations and videos lacked audio descriptions. Blind users were not able to complete this task independently.

Only 60% of blind participants (2 pupils and 4 students) completed the lesson. In comparison, 40% (3 pupils and 1 student) failed the task due to difficulty understanding the material, controlling the content, and feeling physically uncomfortable.

All visually impaired users (100%) experienced difficulty searching for the desired lesson, navigating through its components, and accessing additional information. The lack of an alternative control panel caused physical discomfort, slowed task completion, and increased workload. All participants struggled to distinguish between a pen and a pencil on a virtual whiteboard on one of the platforms. For visually impaired users, it is a challenge to perceive dashed lines on screen drawings and notes. This high visual load leads to rapid fatigue.

Fifty percent of the visually impaired users (1 pupil and 4 students) completed the lesson. The remaining 50% (5 pupils) were unable to

complete the lesson due to difficulties with content perception, navigation, and physical discomfort.

6. All three platforms presented a challenge for 100% of blind and visually impaired users when checking their answers. Blind users, in particular, struggled with page navigation. On one platform, for example, the text moved to the top and was replaced by the system-generated answer. As blocks such as 'teaching material', 'tasks', 'student response', and 'system response' were not separated, blind users had to analyze the text line by line to identify the individual sections. This made interacting with the content time-consuming and tedious.

On another platform, the correct answer was indicated by a color only. Since screen readers cannot recognize color-based cues, blind users had to rely on external help. None of the blind participants were able to solve this task independently.

All visually impaired users had difficulties due to the poor formatting and the large amount of information. Although the task required considerable physical effort and time, they were eventually able to solve it.

7. Only the visually impaired participants (100%) were able to communicate successfully via the tested platforms. They reported no significant difficulties in completing the task.

In contrast, 60% of the blind users (5 pupils, 1 student) had difficulties with the unlabeled menu buttons, which the screen readers identified as "button without label 1", "button without label 2", etc. They were unable to solve the task.

To solve this task, 30% of the blind users (3 students) relied on their logic. They navigated between buttons labeled with symbols using the arrow keys and activated actions utilizing the spacebar. If they were unsuccessful, they returned to the home page. Despite their efforts, none of them managed to solve the task.

Additionally, 10% of blind users (1 student) encountered technical difficulties and required assistance from sighted individuals.

From the results, it can be concluded that blind and visually impaired people, unlike sighted users, often have to guess the function of digital aids while keeping track of various navigation information, focusing on details, and seeking help from sighted users. Their success in completing user tasks also depends on their ability to navigate the keyboard, visualize the page structure, choose appropriate problem-solving strategies, and respond quickly to changing conditions. All these factors,

together with the quality of the content, have a direct impact on the efficiency and speed of their work.

The results of Task 8, summarized in Table 1, indicate that developers of digital learning environments frequently overlook key accessibility principles.

Table 1

Accessibility of Text, Audio, Video Materials, and Other Tools

Parameter	Initial Condition	Accessibility Assessment
Perceptivity	• Button icons lack text labels. • Icons are small and faint; • Fonts are small, light gray on white or light blue background; • Overuse of emojis, overlapping images; • Central control panel in gray; • Smartboard lines are low contrast and dashed	Web content does not meet the perceptivity principle
Operability	• No alternative version of the site for visually impaired users; • Navigation using Tab and Enter is difficult; • Pages lack subheadings; • “Notification” and “Interactive Control” buttons are not voiced; • Video player buttons are labeled in English; • Hard to adjust settings like “change content” or “theme”; • Few hyperlinks are available; • Smartboard tools (pen, pencil) look identical	Web content does not meet the operability principle
Clarity	• Excessive and redundant information; • No text alternatives for audio and video content; • Many sections per page; navigation requires the arrow keys; • Overloaded with text; • Inconsistent design across sections; makes it harder to navigate through web pages	Web content does not meet the clarity principle
Reliability	• Platform functionality is unclear and unpredictable; • Content is largely incompatible with screen readers	Web content does not meet the reliability principle

According to the data presented in Table 1, the degree to which content meets the criteria of perceptibility, usability, clarity, and reliability influences the motivation of blind and visually impaired users to work with digital tools and affects their self-esteem and desire for autonomy compared to sighted people.

A statistical data analysis method was used to validate the results obtained when solving user tasks. The analysis of statistical differences

between the two independent groups, performed using the Kolmogorov-Smirnov test, is shown in Table 2.

Table 2

Statistical Data Analysis

Parameter	Category		$p_{k\text{-}s}$
	Blind	Visually Impaired	
Percentage of the Tasks Completed Independently	0.37 ± 0.49	0.83 ± 0.38	$p < 0.001$

The value of the Kolmogorov-Smirnov test is below the threshold ($p < 0.05$), indicating a statistically significant difference between the two groups. Therefore, the results of the multiparametric assessment of the user experience of blind and visually impaired participants can be considered reliable.

Discussion. Based on the data we obtained while testing digital learning environments (DLE) of online schools, we highlight important points that we believe should contribute to the development and adaptation of web tools for people with visual impairments, both in our country and internationally.

1. The development of DLEs that are accessible to people with visual impairments cannot be done effectively by developers working in isolation or relying on the experience of a single company or country. This results in valuable international knowledge being overlooked, often perceived as unattainable. As a result, developers usually rely on subjective experience and limited information, which can lead to impractical solutions.

On a global scale, this situation leads to an imbalance in internet access between countries, which inevitably affects the quality of online education worldwide. A viable solution would be to create an international database of the most effective and inclusive designs for digital platforms.

2. The design of accessible DLEs should be based on uniform standards established by international law and ratified by individual countries. An example of such an approach is the Convention on the Rights of Persons with Disabilities. This step would help eliminate the legal ambiguity that exists in some countries where specific regulations formalize accessibility efforts, while others treat such regulations as optional. The legal systems of countries with extensive experience in regulating accessibility issues could serve as a basis for such a normative framework. This approach would help standardize national regulations

and make their implementation mandatory, promoting greater consistency and inclusivity across all digital platforms.

3. The design of accessible DLEs requires the adoption of a uniform accessibility criterion. It can be based on the Web Content Accessibility Guidelines (WCAG), which are also supported by the Russian GOST R 52872-2019. According to the WCAG, there are three levels of accessibility for visually impaired users: Level A (basic), Level AA (improved), and Level AAA (optimal). Platforms are generally suitable for visually impaired users if the developers declare that they meet accessibility level AA. If the highest level (AAA) is claimed, the content is designed to be suitable for blind users with residual vision or for users with tunnel vision. However, the official guidelines make it clear that the AAA level is not a mandatory standard for all DLEs, as not all materials can realistically meet all AAA requirements.

4. Developing an accessible DLE requires a unified algorithm that aims to solve common problems that occur on many web platforms. As such:

A. Simplify the registration process or extend the time to enter a user verification code.

B. Develop a unified platform builder that allows flexible customization of components to individual user needs and supports content variability, different visualization formats with identical content. The design should be based on the Russian GOST R 52872-2019, which follows the WCAG framework. The platform builder should be an open-source program (e.g., a cross-platform editor such as Visual Studio Code (VS Code), developed by Microsoft, could be used [6]). The modern programming language JavaScript, which can interact directly with HTML in the browser, offers a wide range of functions. It enables dynamic, interactive content and improves the user's interaction with DLE.

C. he design of the DLE should be adapted to the needs of visually impaired users, taking into account current standards for the adaptation of visual elements. A standards-based design approach ensures the correct display of content on different screen sizes.

D. Severely visually impaired users (0.05–0.09% visual acuity) should have access to an alternative 'low vision' version of the website, along with the ability to return to the default view. Although this is often considered optional, we argue that such a version will increase the flexibility and effectiveness of the learning process. Most importantly, work productivity is ensured by a straightforward interface and easy

management of tools. These are crucial factors for blind and visually impaired learners, whose digital literacy is often still low, even in adolescence. A standardized model, which some government agencies have already adopted, can serve as a basis for this approach. According to the guidelines, access to the alternative version of the platform must be possible from the homepage. The button, which is often represented by a graphic symbol, should be accompanied by high-contrast text. The alternative page should include a special settings panel that allows users to customize the following parameters: Font size: standard, medium or large; Color filter; Font: switch to Arial or Times New Roman; Letter spacing (kerning): Standard, medium or wide; color scheme options: white text on black background, dark blue text on light blue background, brown text on beige background, green text on brown background; visual content: turn images on/off; brightness and contrast of all elements; cursor adjustment: size and color of mouse pointer and text cursor; screen magnifier; screen reader: adjustable speech speed, pitch and volume. To improve usability, the alternative version should be accessible across multiple platform pages while the content remains identical.

E. Ensure compliance with the contrast standards defined by WCAG and GOST R 52872-2019, as text contrast significantly affects readability for visually impaired learners. For accessibility level AA, the visual presentation of text and text embedded in images must have a contrast ratio of at least 4.5:1. An exception applies to large-format text (enlarged text or graphic text), for which a minimum contrast ratio of 3:1 is required. According to the highest contrast requirements of accessibility level AAA, the visual presentation of text and graphic text must have a contrast ratio of at least 7 : 1. Exceptions apply to large-format text, which must have a minimum contrast ratio of 4.5 : 1. The standards also emphasize that the size and weight of the font influence the perceived contrast. According to current standards, the following parameters should be observed: Large font sizes should be between 18 and 24 points, while bold text should maintain a size of 14 points. For optimal readability, fonts must have a minimum contrast ratio of 3 : 1 for good accessibility and 4.5 : 1 for excellent accessibility. Designers can verify these parameters using specialized tools, such as the Contrast Checker, which analyzes hexadecimal color codes for text/background combinations.

F. Special attention should be paid to font families, i.e., fonts that differ in weight and size but have the same design characteristics.

Instructional materials for visually impaired students are usually printed in sans serif fonts, such as Arial, which do not contain distracting details and reduce visual fatigue. The same principle should apply to web content, as sans serif fonts are generally easier to read on screens. For large sections of text on web pages, it is recommended to use sans-serif fonts for headlines and serif fonts for the body text.

G. When designing accessible DLEs, horizontal scrolling should be avoided. Students with severe visual impairments often struggle to control the cursor within the standard scroll range, which can result in limited page functionality and the loss of some content. However, there is not yet enough data to determine how such losses affect overall comprehension of website content. This approach aligns with the WCAG and GOST R 52872-2019 guidelines on text resizing. According to AAA-level accessibility standards, text should be scalable up to 200% without requiring assistive technologies. This allows visually impaired users to read the content in full-screen mode without relying on horizontal scrolling.

H. A standardized text layout should be implemented on all DLE pages. According to WCAG and GOST R 52872-2019, text blocks must be arranged to ensure readability for users with visual impairments. The following formatting rules apply for accessibility level AA: Letter spacing should be 0.12 times the font size; word spacing should be 0.16 times the font size; line width should not exceed 80 characters in a 14-point font; line spacing within a paragraph should be 1.5 times the font size; and spacing between paragraphs should be twice the font size. According to accessibility level AAA, the width of a line of text in a standard 18-point font or a bold 14-point font should not exceed 80 characters. Additionally, the text should not be aligned both left and right at the same time.

I. Blind users should have unrestricted access to PDF files and graphical content on websites with the help of screen reader software. These programs convert screen information into speech and/or a tactile Braille display. To ensure accessibility, PDF files must contain a readable text layer. Decorative graphic elements are exempt from this requirement. Newer versions of screen readers can describe simple images, but excessive descriptions can distract blind users from the actual content.

J. It is essential to ensure stable synchronization between DLE and assistive technologies such as screen readers and screen magnifiers that are intended to support interaction with visual information. To achieve

this, developers should increase their knowledge of the functions of these assistive technologies, understand how the information is displayed, and ensure compatibility with major operating systems and browsers. Including visually impaired people in the development of DLE is also an important step towards creating accessible platforms.

5. Accessible DLEs must offer explicit content. This applies to both the clarity of the textual information and the user interface. Educational and reference materials should be written with the needs of learners in mind. It is necessary to maximize the use of web technologies and APIs, from proper language markup to interaction with screen access programs, to ensure that the content is understandable and the user interface is user-friendly for visually impaired users.

As mentioned above, the highest accessibility standards (AAA level) apply to the entire website, although it is not always possible to meet all criteria for every single element. According to the AAA guidelines, developers should provide explanations for unusual expressions, idioms, jargon, abbreviations, and complex content. This requirement is particularly relevant in educational contexts for users with visual impairments, as their language is often characterized by verbalism – that is, they know the dictionary meanings of words without fully understanding their applications in real-life situations. One possible solution is the use of tooltips or pop-up hints, which can be implemented in HTML. However, this method is not readily applicable to PDF documents. In addition, the practical applicability and technical feasibility of such explanations remain open questions.

Conclusion. The proposed approach to developing digital learning environments (DLEs) that are accessible to users with visual impairments is a complex process. As the analysis of currently operating online school platforms shows, this issue has not yet been fully addressed.

The development of accessible DLEs requires the consideration of international and national experiences as well as the creation and ratification of a uniform legal framework based on existing laws. It also involves consideration of how blind and visually impaired users process web-based information, navigate digital environments, and interact with screen-reading and screen-magnification programs. The study highlights the urgent need to establish standard web content accessibility criteria for all developers.

The information presented broadens the understanding of how to design content that is accessible to people with visual impairments and

the challenges these users face on websites. The proposed framework can be utilized by developers creating digital tools designed not only for individuals with visual impairments, but also for other vulnerable groups.

It is a global issue because digitization involves not only the creation of a web space accessible to all users regardless of their psychophysical abilities, nationality or educational background, but also the preparation of qualified professionals and developers, the training of educators who can teach users how to use these tools, the promotion of skills for socialization and communication in the digital environment and the creation of a legal framework that regulates interactions on the Internet.

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ПСИХОЛОГО-ПЕДАГОГИЧЕСКИЙ АНАЛИЗ ДОСТУПНОСТИ И ПРОЕКТИРОВОЧНЫХ РЕШЕНИЙ ЦИФРОВОЙ ОБРАЗОВАТЕЛЬНОЙ СРЕДЫ ДЛЯ ОБУЧАЮЩИХСЯ С НАРУШЕНИЯМИ ЗРЕНИЯ

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Аннотация. В эпоху глобальной цифровизации особую актуальность приобретают проблемы проектирования веб-контента, ориентированного на потребности разных категорий пользователей, в том числе и лиц с нарушениями зрения. В России данная деятельность регламентируется ГОСТ Р 52872-2019 и приказами Минцифры России. Однако в нашей стране соблюдение норм, определяющих проектирование доступной цифровой образовательной среды, носит добровольный характер. В результате слепые и слабовидящие пользователи нередко сталкиваются с трудностями, возникающими у них при доступе к цифровым образовательным, развлекательным и социальным сервисам. Сложившаяся ситуация обусловила необходимость выявления актуального состояния доступности онлайн-платформ для слепых и слабовидящих пользователей, поиска оптимальных решений, обеспечивающих доступность цифровой образовательной среды лицам с нарушениями зрения. При работе свое применение нашли методы (эвристический, анализ данных, тестирование, обобщения полученных результатов, статистической обработки данных (критерий Колмогорова-Смирнова), методики оценки индекса клиентских усилий (Customer Effort Score) и элементы построения карты-пути пользователя (Customer Journey Map, CJM). Пользователям предлагалось решить 8 стандартных пользовательских задач. В исследовании на добровольной основе задействовались 10 слепых и 10 слабовидящих обучающихся в возрасте от 15 до 20 лет из городов Москва, Ульяновск и Чебоксары. Результаты исследования позволяют расширить представления об особенностях работы слепых и слабовидящих пользователей в условиях цифровой образовательной среды. Согласно полученным данным, проектирование цифровой образовательной среды предусматривает необходимость учета международного и отечественного опыта; создание общей нормативной базы для всех стран; анализа доступности веб-инструментов; ориентации на особенности восприятия информации слепыми и слабовидящими, их навигации в цифровом пространстве, функционирования программ экранного доступа и программ увеличения экрана; принятия общих для всех разработчиков критериев доступности контента. Представленные данные найдут применение у разработчиков и исследователей, решающих проблемы создания цифровых инструментов для лиц с нарушениями зрения и других категорий пользователей.

Ключевые слова: *лица с нарушениями зрения; доступность; цифровая образовательная среда; разработка*

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