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OPTIMIZACIJA TAMNOG NAČINA RADA KROZ ANALIZU UČINKA BOJE POZADINE NA BRZINU I TOČNOST ČITANJA

OPTIMISATION OF DARK MODE THROUGH ANALYSIS OF BACKGROUND COLOUR IMPACT ON READING SPEED AND ACCURACY

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SAŽETAK

Korisnička sučelja su način na koji korisnici mogu komunicirati s računalnim ili bilo kojim drugim digitalnim sustavom. Dobro dizajnirano sučelje korisnicima omogućava jednostavnu, ali funkcionalnu interakciju, te pruža dobro korisničko iskustvo i zadovoljavajuću vizualnu estetiku pomoću elemenata poput boje ili tipografije. Krajem prošlog desetljeća pojavio se trend u dizajnu korisničkog sučelja nazvan „tamni način rada“ koji postaje sve popularniji. Popularnost tamnog načina rada može se pripisati estetskoj privlačnosti i mogućim prednostima poput smanjenja naprezanja očiju ili smanjenju potrošnje baterije zbog korištenja svijetlog teksta na tamnoj pozadini.

Cilj ovog rada je proučiti utjecaj različitih nijansi pozadina tamnog načina rada na čitkost teksta. Proučavanjem utjecaja tamnih pozadina na vrijeme i preciznost čitanja, nastoji se pronaći optimalnu boju pozadine za tamni način rada. U sklopu ovog rada provedeno je istraživanje u kojem su ispitanici na mobilnom uređaju čitali tekstove na različitim tamnim bojama pozadina. Dva parametra koji su analizirani u svrhu ovog istraživanja bili su vrijeme potrebno za čitanje tekstova i broj pogrešaka pri čitanju.

Rezultati su pokazali da odabir boje pozadine ima značajan učinak na sposobnost čitanja. Osobito se pokazalo da specifična nijansa tamno sive (#121212) značajno smanjuje broj pogrešaka pri čitanju, dok se tamno plava (#15202B) pokazala kao najbrža za čitanje.

Ključne riječi: *tamni način rada, mobilna sučelja, čitkost teksta, korisničko iskustvo*

ABSTRACT

User interfaces are the means by which users can interact with computer or any other digital system. A well-designed interface allows users to interact easily yet functionally, providing a good user experience and satisfying visual aesthetics through elements such as color or typography. At the end of the last decade, a trend in user interface design called "dark mode" emerged and is becoming increasingly popular. The popularity of dark mode can be attributed to its aesthetic appeal and potential benefits such as reduced eye strain or decreased battery consumption due to the use of light text on a dark background.

The aim of this paper is to examine the impact of different shades of dark mode backgrounds on text readability. By studying the effect of dark backgrounds on reading time and accuracy, the goal is to find the optimal background color for dark mode. As part of this study participants read texts on a mobile device with various dark background colors. The two parameters analyzed for this research were the time required to read the texts and the number of reading errors.

Results showed that the choice of background color has a significant effect on reading ability. In particular, a specific shade of dark grey (#121212) was found to significantly reduce the number of reading errors, while dark blue (#15202B) proved to be the fastest for reading.

Keywords: *dark mode, mobile interfaces, text readability, user experience*

1. INTRODUCTION

User interfaces are the means by which users can interact with a computer or any other digital system. A well-designed interface allows users to engage in simple yet effective interaction, providing a good user experience, functionality and satisfying visual aesthetics through elements like colors and typography.

Interface elements can be graphical, textual, or audiovisual and users interact through tools such as a computer mouse or microphone. Interfaces and their usage vary across devices. Computers are typically operated using a keyboard and mouse, digital watches have buttons for setting the time or activating a stopwatch, while modern mobile devices require only touch. [1]

In user interface design, the choice of color plays a significant role. Beyond pure aesthetics, well-chosen colors in a user interface can also enhance the user experience and influence decision-making. However, user interface design should start with only black and white to successfully create a clean and simple design. Overusing colors at the very beginning can have a highly negative impact on the interface itself. Only after designing the layout of the interface do colors come into play, and are used to emphasize specific elements. [2]

One rule for using colors is the 60-30-10 rule, which states that in design, 60% should be the dominant color, 30% the secondary color, and 10% reserved for accents. Applying this rule achieves harmony among the elements in the design. [3]

Color psychology also plays an important role in choosing colors, as it allows associations between colors and certain emotions or moods. For example, it is known that blue has a calming effect on the viewer, which is why companies related to finance or technology use it in their designs to build user trust. [4]

Typography is the art of shaping the size, appearance, and structure of text to create content that is readable, clear, and visually appealing to the user. The goal of typography in interface design is to evoke a specific reaction or convey a particular message to the user, while the designer's objective is to ensure the readability and clarity of the interface. [5]

Before beginning to read a website or mobile application, a user scans the content. Therefore, it is important to have a clear hierarchy and legible typography to create a good first impression for the user. After that, it is crucial to convey the intended message to the user, and the designer's goal is to ensure that typography contributes to conveying the message rather than interfering with it. [5]

When formatting text in an interface, it is important to adhere to certain rules. Some fonts have their own personality that affects expectations and the message conveyed to the user. It is recommended to use 2 fonts, one for headings and another for the main text. When combining different fonts, mixing font types can be helpful, for example, combining a serif and a sans-serif font. [6] For general application, Verdana has proven to be the best font for display on digital screens. [7]

The hierarchy of elements in user interface design refers to the manipulation of certain interface elements to create a specific structure that would achieve a satisfactory user experience when using the product.

The first way to emphasize elements is through the size of the element itself. The larger an element, such as a heading, the more it stands out and attracts the user's attention. Bright colors stand out more than muted ones, and can be further emphasized through the use of contrast. [8]

Alignment of elements contributes to the structure of the interface layout and provides the user with a better content reading experience. Center alignment of text is usually used for calls to action. Repetition of the same or similar elements in design creates consistency, thereby improving the user experience by creating a sense of comfort for the user due to familiarity with the interface. Typography, colors, shapes, etc. can be repeated. [8]

When reading any content, people start at the top and look downward, which is a universal rule across all cultures worldwide. Jakob Nielsen's research revealed that the most common reading pattern follows the shape of the letter F. This means that users' gaze typically forms a horizontal line at the top of the text, another shorter horizontal line slightly lower in the content, and then scans vertically down the left side of the content. [9]

Later research showed that in languages read from right to left, the F-shaped pattern is also present but mirrored, with the vertical line appearing on the right side. [10]

In addition to the F-pattern, the Z-pattern is also popular. To achieve a Z-pattern, it's necessary to guide the user's eyes to follow a line in the shape of the letter Z, meaning their eyes first trace a line from the top left corner to the top right, then diagonally to the bottom left, and finish in the bottom right corner. Unlike the F-pattern design, which is applied to pages with a lot of textual content such as articles or search results, the Z-pattern is used in more minimal designs where less emphasis is placed on textual content. Information from point to point of the letter Z should be presented from most important to least important, with a call to action at the end. The central part of the page usually contains an image that keeps the user interested while separating the top and bottom parts of the page. [11]

2. DARK MODE

Dark mode refers to user interfaces displayed in dark colors, typically serving as an alternative to conventional light themes. The purpose of dark mode is to reduce the amount of light emitted by screens while maintaining a minimum color contrast ratio. One of the reasons for using dark mode is the assumption that it helps alleviate eye strain for users, especially during prolonged screen use.

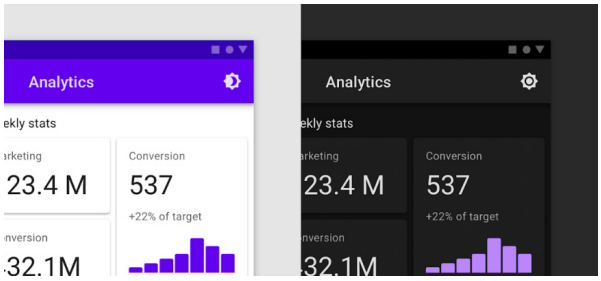


Figure 1 *Comparison of dark and light modes in user interface (Source: https://m2.material.io/design/color/dark-theme.html)*

2.1. HISTORY OF DARK MODE

In the 1970s and 1980s, cathode ray tubes were the standard, so computer monitors at that time used CRT technology. By definition, a cathode ray tube is "a complex electronic tube that illuminates a fluorescent screen with an electron beam to create an image.“ [12] CRT Screens at that time were not capable of illuminating the entire surface, so a dark background with white or green text was used. [13] Therefore, it can be said that dark mode was the only choice at that time due to technological limitations.

During the 1980s and 1990s, graphical user interfaces developed sufficiently for the industry to switch to light mode, where text was in dark colors, displayed on a white background. The purpose of this transition was to mimic the feeling of a table desktop, where the white background would give users the experience of reading from paper. [13]

Although light mode became the standard, dark backgrounds continued to be used in special circumstances, such as programming or in design tools. Dark backgrounds were also used on pages such as luxury brands to give the customer a sense of being part of the elite. [14]

In the late 2010s, dark mode slowly returned to use, and several factors were responsible for the comeback of dark mode. OLED displays are the only type of displays that save energy in dark mode, which is possible because OLED displays do not illuminate unnecessary pixels. [14]

Today, dark mode is offered by almost all leading applications and operating systems on both computers and mobile devices.

2.2. CHARACTERISTICS OF DARK MODE

The fundamental visual characteristic of dark mode is the use of high contrast between foreground elements and background. A typical background is black or dark gray, while text and other user interface elements are lighter in color. The purpose of this inverted color scheme is to reduce the overall screen brightness, which is beneficial in low-light conditions. However, it's necessary to achieve a balanced contrast. Too low contrast can worsen readability, while too high contrast can cause visual discomfort for users. [15]

Choosing the background color is crucial for establishing contrast balance. It's recommended to avoid pure black (#000000) because, especially in combination with pure white (#FFFFFF), the contrast becomes too high and becomes hard on the user's eyes. Nevertheless, on OLED displays, pure black backgrounds can be used because unlit pixels turn off, thus achieving greater energy efficiency. [15]

It's much safer to use dark gray colors for the background because light text on a dark gray background has less contrast than black, and it's also easier to display depth and a wider spectrum of colors on dark gray backgrounds. The Material Design website recommends a dark gray shade of #121212 (Figure 2). [16]

Figure 2 *Recommended shade of gray according to Material Design website (Source: https://m2.material.io/design/color/dark-theme.html)*

Pure white text (#FFFFFF) can be used with the specified background color, provided that the text opacity is reduced to further decrease contrast. In addition to reducing contrast, decreasing text opacity is important for emphasizing certain elements. [16],[17]

Research has shown that dark mode can indeed have an impact on eye strain. One study conducted on smartphones demonstrated that, in conditions of bright ambient light, eye fatigue was on average lower on a dark background, while in conditions of low ambient light, eye fatigue on a dark background was actually higher. [18]

On computers, programming tools are generally designed with dark themes to improve the user experience for those working for extended periods in low-light environments. Adding dark mode as an option for users also increases user satisfaction due to the ability to control their own experience. [19]

3. EXPERIMENT

In the practical part of the study, research was conducted to determine if the background shade in dark mode affects text readability. For this research, color palettes used in some of the most popular applications and social networks were selected. Six variations of dark themes with different background colors were created, featuring short texts that were read aloud. Thanks to an equal number of characters and words, all texts had a similar reading difficulty.

The aim of this research is to examine whether the background color will influence reading time and the number of errors during reading. The total number of participants was 51, but after removing extreme values, 46 valid results remained. The participants were students from the University North, ranging in age from 19 to 23 years, of which 20 were male and 26 were female.

Participants read texts on different dark backgrounds from a smartphone. Two parameters analyzed for this research were the time required to read the texts and the number of reading errors.

3.1. CREATING THE USER INTERFACE

For the purpose of this research, a user interface was created in the form of a mobile application with six variations of dark themes used on various websites and applications. Apart from the initial screen, all screens use texts from CARNet's presentation on internet safety, processed to have a uniform word count. The Verdana font was chosen for the texts due to its superior readability on digital screens. [7] The text size is 15 pt, with 18 pt line spacing, while the text headings are 24 pt in size, with 29 pt line spacing.

The first text had a pure black background. The background of the second text is dark gray as recommended by Material Design. The third text uses a shade of gray employed by the popular social network Facebook, while the shade of gray used for the fourth text is utilized by Discord, a messaging application. The fifth color is dark blue, similar to the one used in the dark theme of the social network X (Twitter). The sixth and final background is an example of dark purple used in various themes in applications that allow customization of the user interface, such as programming tools. The chosen shade of purple was derived from the "Beautiful Purple Sky"

theme for Firefox using a color picker tool. The selected colors are shown in Figure 3, which shows the layout of the text selection menu.

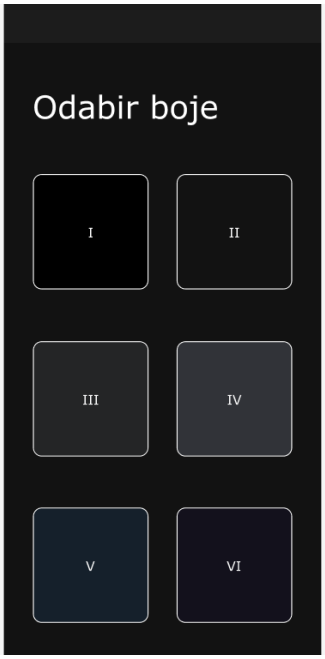


Figure 3 *Display of the text selection menu (Source: author)*

All six texts were given to the participants to read one after another (Figure 4). All participants used the same mobile device for reading. The mobile device was a realme GT Master Edition, model RMX3363, with a 6.43-inch screen diagonal. The participants read the texts aloud, which was recorded using the built-in microphone on the phone, using the 'Recorder' application. The collected recordings were listened to in order to measure the duration of the reading of each text and the number of errors made while reading the texts. Microsoft Excel was used to process the obtained results.

4. RESULTS AND DISCUSSION

In this study, two parameters were measured: the time required to read the texts and the number of errors made during reading. To determine which background color yields the best results, a table was created showing the total number of errors for each text, expressed both numerically and as a percentage (Table 1).

Table 1 *Number of errors per text, expressed as a number and percentage.*

Visual presentation	Text (background color)	Total number of errors	Percentage
I	Text 1 (#000000)	73	24.58%
II	Text 2 (#121212)	30	10.10%
III	Text 3 (#242526)	61	20.54%
IV	Text 4 (#313338)	53	17.85%
V	Text 5 (#15202B)	34	11.45%
VI	Text 6 (#13111C)	46	15.49%
	TOTAL	297	100%

The obtained results confirm the fact that a pure black background is not suitable for reading. The background of text 1, color #000000, proved to

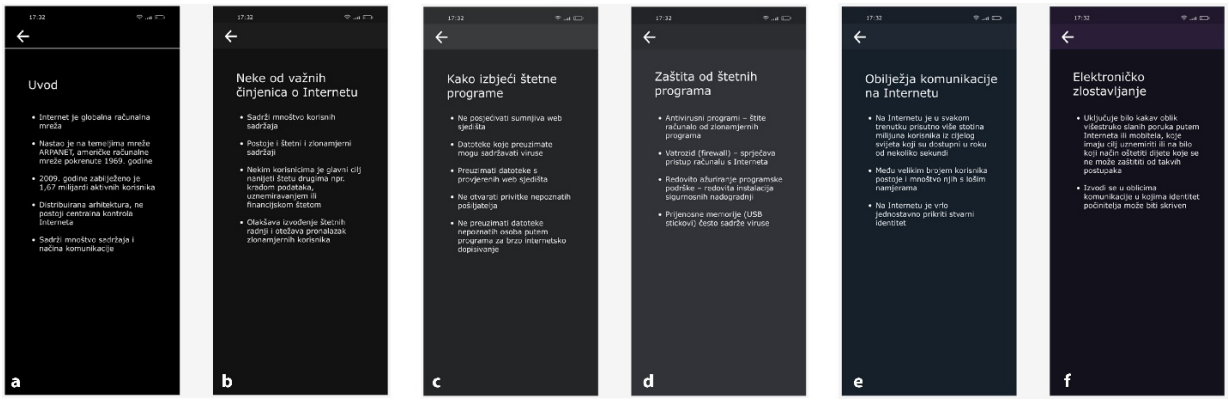
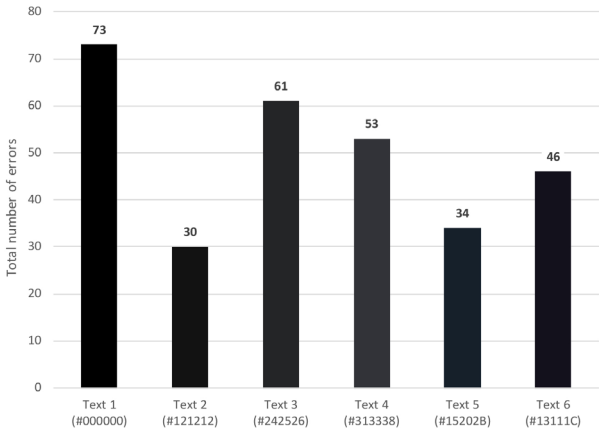


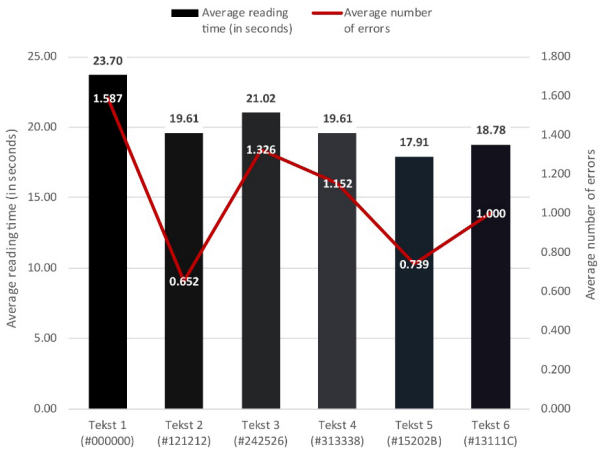
Figure 4 *Examples of dark backgrounds and text: a) Pure black background - #000000, b) Material Design gray - #121212, c) Facebook gray - #242526, d) Discord gray - #313338, e) Twitter/X blue - #15202b, f) Purple Sky violet - #13111c (source: author)*

be the worst with 73 errors, which is almost a quarter of the total number of errors. The three colors that proved to be the best, that is, where the participants made the least mistakes, from the lowest number of errors upwards, are text 2, with background color #121212 (30 errors), then text 5, with background #15202B (34 errors), and text 6, with background #13111C (46 errors).



Graph 1 *Graphical display of the total number of errors per text*

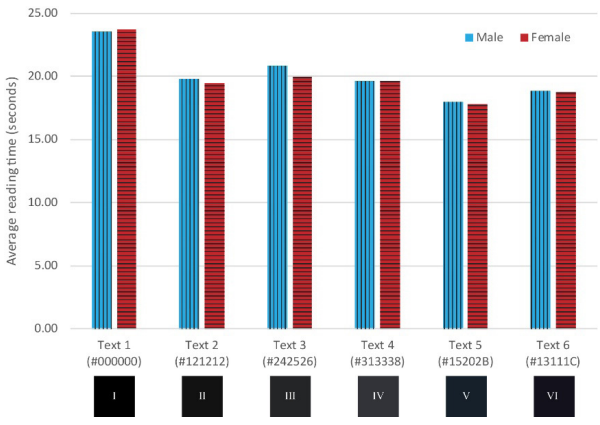
In addition to the number of errors, the time required to read each text was also measured, rounded to two decimal places for greater precision. According to the presented graph (Graph 2), participants also needed the most time to read text 1. Based on the obtained results, it is clear that the pure black background stands out as the worst choice according to both parameters. Among the texts that were read the fastest, from fastest to slower are text 5 (17.91 seconds), then text 6 (18.78 seconds), and text 2 and text 4, which are almost identical in average reading time (19.61 seconds for both texts).



Graph 2 *Ratio of average reading time to number of errors*

Although it was established which background is the worst for dark mode, the results for the best one vary depending on the parameter. While for reading time, the best background color proved to be #15202B, the dark blue color used on the social network X, which is interesting because this social network is based on the idea of short posts that are quickly read, the highest reading accuracy was still shown on the background #121212, Material Design dark gray. To determine which color is optimal to use in dark mode design, ratios of average reading time and number of errors were calculated, and the data is shown in Graph 2.

Using the data obtained from the research, it is also possible to compare the results of all measurements depending on the gender of the participants. The participants were students of which 20 were male and 26 were female. By comparing the average number of errors and reading time between male and female participants, the intention is to examine how much influence the background color can have depending on gender. The data is presented graphically, with blue chosen for male and red for female participants. Graph 3 shows the differences in average reading time depending on gender. It can be noticed that the only text with a significant difference in reading time is text 3, which male participants on average read almost a second longer.

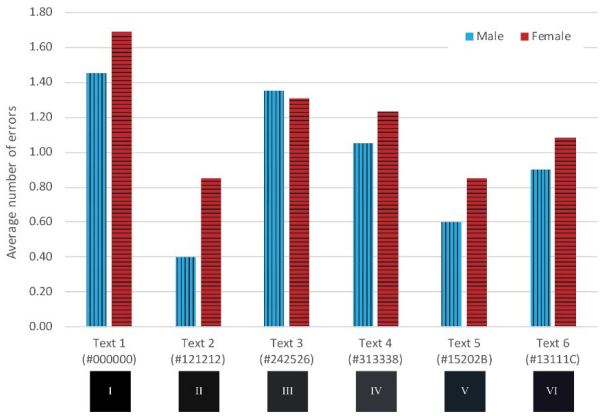


Graph 3 *Analysis of the difference in average reading time between male and female participants*

The differences between male and female participants become much more apparent when looking at errors. During reading, male participants made significantly fewer errors than

female participants but they read longer. One exception is text 3, which also stood out in the reading time measurement as a text that male participants took longer to read. The biggest difference in the number of errors is in text 2 (#121212), as shown on Graph 4.

Similar results were obtained in a study by Zorko et al. [20], in which subjects who had the longest reading time had the fewest errors.



Graph 4 *Analysis of the difference in the average number of reading errors between male and female participants*

5. CONCLUSION

Dark mode was initially used out of necessity, but at the end of the last decade, it returned as an alternative to light mode. Thanks to its attractive aesthetics and the advantages it offers, it didn't take long to gain popularity. Today, it can be found as an alternative, or in some cases as the standard, on a large number of websites, applications, and operating systems

The aim of this study was to investigate the impact of different dark mode background shades on text readability. The results of this research showed that the choice of background color in dark mode can have a significant effect on text readability, as evidenced by both reading speed and error count. Dark gray (#121212) recommended by Material Design stood out as particularly effective in reducing reading errors. Although the same color offered high reading speeds, dark blue (#15202B) used on the social network X proved to be the fastest for reading, despite participants making more errors.

The study also revealed a need for balanced contrast. Despite energy efficiency on OLED displays, pure black (#000000) showed the worst impact on text readability. Participants spent significantly more time and made considerably more errors on pure black backgrounds.

Furthermore, analysis of results by gender revealed certain differences between male and female participants. Male participants had fewer reading errors, while female participants had shorter average reading times. A possible explanation for these results is that female participants simply made more errors during reading because they were rushing, while male participants had longer reading times and fewer errors due to more careful reading.

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Sveučilište Sjever, a od 2016. godine je grafički urednik časopisa Tehnički Glasnik / Technical Journal. U svom radu proučava utjecaj boja i tipografije na čitkost tekstualnih sadržaja, kao i ulogu animacije i pokreta u usmjeravanju pažnje korisnika u digitalnim sučeljima. Teži stvaranju estetski uravnoteženih, funkcionalnih i intuitivnih sučelja koja unapređuju korisničko iskustvo. Pojedina istraživanja unaprijedila je koristeći eye tracking kameru kako bi detaljno analizirala obrasce vizualne percepcije korisnika tijekom interakcije s grafičkim sučeljima s ciljem razumijevanja kako boja, tipografija i pokret utječu na usmjeravanje pažnje.

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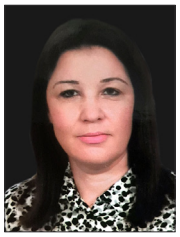
• **Anja Zorko** - Diplomirala je 2012. godine na Grafičkom fakultetu Sveučilišta u Zagrebu, a trenutno je doktorandica na poslijediplomskom studiju Grafičko inženjerstvo i oblikovanje grafičkih proizvoda. Od 2015. godine zaposlena je na Sveučilištu Sjever, na Odjelu za multimediju, najprije kao vanjska suradnica, a od 2022. godine kao predavač. Sudjeluje u izvođenju nastave na kolegijima Multimedija, oblikovanje i primjena, Grafički alati 1, Grafički alati 2 te Uvod u medije na odjelu Glazba i mediji. Mentorica je studentskih radova iz područja grafičkog dizajna, pripreme grafičkih materijala i primjene novih tehnologija u vizualnim komunikacijama. Suautorica je autoriziranih predavanja "Obrada bitmap grafike". U svojim objavljenim radovima istražuje korisničko iskustvo, utjecaj dizajna i digitalnih sadržaja te doprinosi optimizaciji vizualnih rješenja. Osim nastavnih i znanstvenih aktivnosti, aktivno sudjeluje u pripremi i izradi digitalnih i tiskanih grafičkih materijala za potrebe Sveučilišta.



• **Nikolina Bolčević Horvatić** - Diplomirala je 2010. godine na Grafičkom fakultetu Sveučilišta u Zagrebu, gdje je trenutno i doktorandica na studiju Grafičko inženjerstvo i oblikovanje grafičkih proizvoda. Svoj radni put započela je 2010. godine na Veleučilištu u Varaždinu, gdje je prvo radila kao vanjski suradnik, a kasnije kao asistent. Od 2014. godine do danas radi na Sveučilištu Sjever na odjelu Multimedija, trenutno u zvanju predavača. Njezina uloga u obrazovanju uključuje predavanja i vježbe na kolegijima koji su usmjereni na cjelokupni proces izrade grafičkih proizvoda, od kreativnog dizajna, preko tehničke pripreme i odabira tiskarskih tehnika do finalne proizvodnje i dorade tiskarskog medija. Suautorica je autoriziranih predavanja pod nazivom "Obrada bitmap grafike: teorija, primjeri, zadaci" (S. Ivančić Valenko, A. Zorko, N. Bolčević Horvatić). Aktivno sudjeluje na znanstvenim i stručnim skupovima, a njezini objavljeni radovi i istraživačka područja su usmjerena na unaprjeđenje kvalitete tiska kroz optimizaciju procesa i kontrolu otiska, s ciljem smanjenja grešaka i povećanja preciznosti proizvodnje.

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